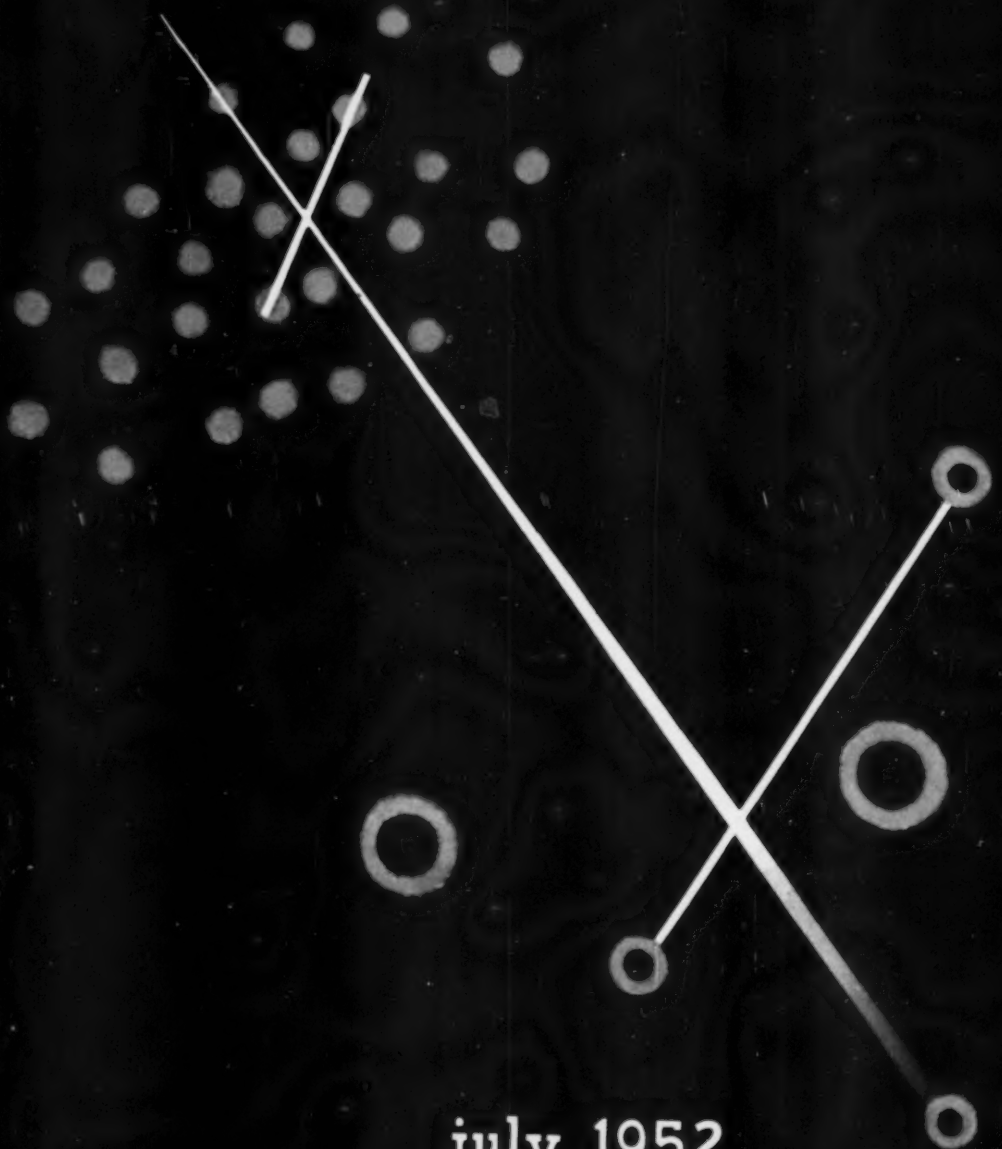
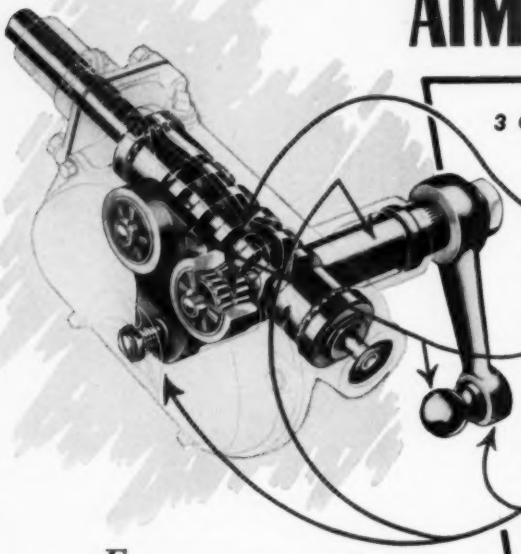
metal progress



july 1952

There's Long, Hard Wear in STEERING GEARS

...PUT THERE BY 'SURFACE' RX PREPARED ATMOSPHERES



3 Controlled Atmospheres for Heat Treating

Work flow in the plant producing this steering gear is arranged around 3 controlled atmosphere processes: *carburizing, dry cyaniding, clean hardening.*

- **Carburizing:** Steering gear cams, the "heart" of the assembly, are carburized in 4 'Surface' pit type radiant tube furnaces each with an enriched RX controlled atmosphere. Each furnace handles about 1500 lbs. net. Minimum hardenable case depth of 0.040-in.
- **Dry Cyaniding:** Studs and balls subject to frictional wear and impact stress in final assembly are given optimum physical properties by a dry cyaniding treatment with a 'Surface' RX atmosphere enriched with natural gas and ammonia. Studs are cyanided to case depth of 0.008-in. Balls are treated to case depth of 0.010-0.015-in. Heat treatments are accomplished in a continuous articulated link belt furnace.
- **Clean Hardening:** Lever shafts and steering arms are first isothermally annealed, then clean hardened in a 'Surface' rotary hearth furnace with radiant tubes and an RX controlled protective atmosphere.

Ever hear of an auto accident due to steering gear going bad? Quite likely you never will, because right before your eyes is proof that steering mechanisms (other parts and products, too) are made safe and dependable.

All vital and moving parts of the steering assembly shown above undergo one or more controlled atmosphere heat treatments: *carburizing, cyaniding, clean hardening,* where results are uniform and consistently within close tolerances.

These controlled atmosphere heat treatments are carried out in radiant tube-fired furnaces of types best suited for handling the particular parts. The furnace types include pit, rotary hearth and continuous articulated link belt types.

RX PREPARED ATMOSPHERES

Atmospheres for these 3 distinctly different heat treat processes are prepared in 2 centrally located 'Surface' RX generators manifolding the RX carrier gas for all atmosphere requirements. Saves money, saves space!

'Surface' RX generators for making prepared atmospheres are employed successfully in hundreds of plants for many processes: carburizing, clean hardening, bright annealing, carbon restoration, homogeneous carburizing and dry cyaniding.

'Surface' is a pioneer in prepared atmosphere equipment, furnishing not only RX, but also DX, NX, HX, HNX, AX and Char-Mo gas atmospheres. *Send for Bulletin SC-155 on prepared atmospheres. Write today on your letterhead.*

'Surface'
INDUSTRIAL FURNACES

SURFACE COMBUSTION CORPORATION · TOLEDO 1, OHIO

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THIS HAS sure been a busy spring with the A.S.M. Always there are more important things to do than there are hours in the day and night.

Assistant Secretary Ray Bayless has received some 60 technical papers for the two meetings of A.S.M., one in Philadelphia Oct. 18 through 24, the other in Los Angeles in March 1953. The Publications Committee under the leadership of Bill Baldwin of Case Tech stewed for two days in selecting the papers and arranging the programs. Now these technical papers go to the printer for typesetting, to the draftsman for redrawing of graphs, to the engraver for halftones, and all must then be put on the presses and assembled for distribution by Sept. 1. So Ray and his staff have their work cut out for them right through convention time.

Ernest Thum, editor of *Metal Progress*, has been going to town getting articles and materials ready in advance for summer issues when he was to be absent. But, lo, the doctors got hold of him, and instead of Ernest's taking a trip to Europe he took a trip to the hospital for a major operation. (All okay now, we are very happy to report.)

Marjorie Hyslop, the new managing editor of *Metal Progress*, is doing a fine job of planning and management, also completing the 1951 volume of The A.S.M. Review of Metal Literature (some 900 pages).

Taylor Lyman, publisher, and Pete Ford, sales manager, had their *Metal Progress* representatives in at the home office to discuss plans for the October convention number and the January 1953 issue of "The Engineering Magazine of the Metals Industry".

And Betty Bryan, new associate editor of *Metals Review*, is beaming with many new plans for increasing *Metals Review* pick-up appeal to members. The July issue will carry the announcement of the convention papers and preprint order instructions.

Chet Wells has been going around the Philadelphia Convention Halls with a tapeline and ruler trying to find a spot here or there that might take care of a firm on the waiting list so it could participate in the big Metal Show this fall. Of course we've had "SRO" before but never quite so early in the season. It just shows that the Metal Show is the Show of Shows. Show me how to show up the big Metal Show with fewer shows. (Hold everything! I won't try to show off again.)

I've been having the choicest job of all — meeting with the newly elected chairmen and vice-chairmen at regional conferences of chapters. Conferences were held in Seattle; Springfield, Mass.; Philadelphia; Detroit and Cleveland. Some 39 chapters were represented, all discussing activities and plans for the coming season. These meetings have been very successful and the prospects are to expand this type of activity next spring. With the vice-president in attendance, it is thought that the conferences need be held but once in two years. Visiting with executive committees and attending chapter meetings constitute the greatest compensations any secretary can receive.

You and we were terrifically shocked to lose two of A.S.M.'s past presidents within a week. Dr. George Waterhouse and Dr. Marc Grossmann served the Society many years and never lost interest in its activities. They made a lasting place for themselves in the records of the organization, one that time can never dull or cause to disappear. They were two of our finest men — they will live in our hearts forever.

Sincerely,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

Typical products centrifugally cast in

thermalloy

Jet Rings
Piston Rings
Radiant Tubes
Composite Rolls
Furnace Hearth Rollers
Retorts—Magnesium, Annealing, etc.
Dry Shafts for steel plants
Furnace Supports
Cylinder Liners
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Feed Pipes

For production of cylindrical shapes in all grades of THERMALLOY*, Electro-Alloys now offers the advantages of high-volume centrifugal casting facilities.

These advantages, as opposed to static castings, include: improved uniformity of wall thickness; finer grain structure and higher density; lower finishing and machining costs—arising from improved dimensional control.

Our centrifugal casting facilities include horizontal axis machines for both sand and permanent molds. In addition, vertical axis machines are available for permanent mold work. High alloy castings of almost any wall thickness, ¼″ and over, can be produced in horizontal sand and permanent molds in sizes from 3½″ to 20″ O. D.—up to 96″ in length; in vertical permanent mold from 20″ to 34″ O. D.

For further information, call your nearest Electro-Alloys sales office, or write Electro-Alloys Division, 2097 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

The Passkey to TOP BRAZING PRODUCTION to BOTTOM BRAZING COSTS

EASY-FLO

Typical Application of the Easy-Flo Brazing Formula

1. THE ASSEMBLY

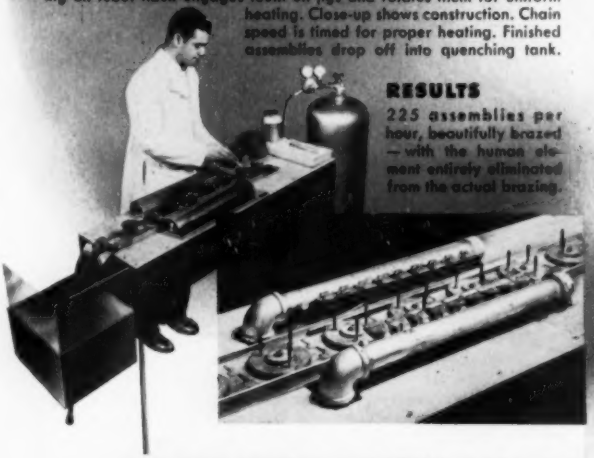
A steel tube and a steel stamping with a ring of 3/64" EASY-FLO45 wire preplaced as at right.

2. THE FAST HEATING METHOD

In this case it's gas-air in 2 parallel rows of burners.

3. THE PRODUCTION SET-UP

A motor-driven endless chain which travels between the rows of burners. Operator assembles parts on jigs on the chain, preplaces the EASY-FLO rings and applies Handy Flux. Vertical pins support and position stamping on tube. Rack engages teeth on jigs and rotates them for uniform heating. Close-up shows construction. Chain speed is timed for proper heating. Finished assemblies drop off into quenching tank.



RESULTS

225 assemblies per hour, beautifully brazed — with the human element entirely eliminated from the actual brazing.

If you need *more* joints per hour—if you need *better* joints—if you need to *cut costs*—you can open the doors to all three with EASY-FLO—the low-temperature silver brazing alloy.

You simply apply the 3-part EASY-FLO brazing formula—(1) *preplace* the alloy—(2) use a *fast* heating method—(3) devise a set-up that will keep assemblies on the move to and through the heating zone. At left is a typical example.

A BRAZING EXPERT IS AT YOUR CALL

We'll be pleased to send a Field Engineer to your plant to help you apply the EASY-FLO formula to your brazing needs. *There's no cost or obligation*—so, why not get the benefit of this man's wide production brazing experience. Just contact our nearest office or dealer and say when you'd like him to call.

GET THE WHOLE AMAZING EASY-FLO BRAZING STORY IN BULLETIN 20... Learn why strength, speed and low cost are inherent in EASY-FLO brazing... also how to design joints and how to get fast brazing production with unskilled labor. Write for this valuable 24-page bulletin today.

85th Anniversary — HANDY & HARMAN — FOUNDED 1867 — QUALITY • SERVICE

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N.Y.

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BRIDGEPORT, CONN.
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◂ Partial view of one of the control panels for C.F. & I. soaking pits. Heater is opening Micromax Controller case to change temperature control point.

▴ Part of C.F. & I.'s battery of 24 Salem soaking pit furnaces in Pueblo, Colo. plant. Control panels are in cubicles in right hand bay.

How C. F. & I. controls pit furnaces to give ingots

correct TEMPERATURE *and* SURFACE

The idea of employing instruments wherever they can be effective is doing a major job for Colorado Fuel & Iron Co. Engineers of C.F. & I. and of Salem Engineering Co. applied it with outstanding success in the soaking pits shown above. The net result is a plentiful supply of well-heated, properly-surfaced ingots from the big battery of 24 Salem round pit furnaces.

Regulation of the furnaces includes automatic control of temperature, combustion (fuel-air ratio) and draft (furnace pressure) in that order. The Micromax Temperature Recording Controllers preserve correct temperatures despite the effects of charging and pulling ingots, and changes in ambient conditions. With this basic fact of temperature under firm control, the other instruments can hold the equally important combustion factors at their correct respective settings. Furnace atmosphere can be made either neutral, oxidizing or reducing at any operating temperature. Draft can be made to hold the products of combustion to their proper path through the furnace for any operating load of ingots.

The L&N line today includes instruments, controllers and accessories in far greater variety than ever before. From among these standard equipments we can help you assemble control panels that are tailored exactly to the needs of any pit furnace . . . or any other industrial furnace. Just contact our nearest office or write us at 4927 Stenton Ave., Phila. 44, Penna.

LEEDS NORTHRUP

instruments · automatic controls · furnaces

Jrl Ad N-33-667(2a)

Metal Progress is published and copyrighted, 1952, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

The PRESSED STEEL Co. PSC

ANNEALING CONTAINERS & COVERS

In Any | DESIGN | ALLOY | SIZE | QUANTITY

Do you need a special type of annealing equipment?...We have designed containers and covers for every imaginable product.

Have you a temperature problem?...We fabricate from the entire list of heat-resisting alloys.

Are size of the equipment or quantity required a cause for consideration?...As indicated by the illustrations, we furnish boxes, baskets, etc., for the smallest parts, or covers for the biggest steel mill anneals -- singly or by carload.

Weigh Up to 2/3 Less. Save Time and Fuel

Here are 4 ways that "Pressed Steel" light-weight annealing units cut costs and speed production, as shown by plant records:

1) FUEL SAVING--Made of light gauge welded sheet alloy, they require less fuel and time to attain pot heat.

2) LABOR SAVING--Handle easier and faster.

3) REPLACEMENT SAVING--Some installations have been in constant service for 20 years.

4) SPACE SAVING--Being less bulky than cast units, installations have frequently doubled furnace capacity.

We furnish a complete line of annealing and carburizing boxes, covers, baskets, racks, tubes, retorts, etc. As pioneers of sheet-alloy heat-treating equipment, we offer a wealth of experienced engineering assistance. Send blue prints or write as to your needs.

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

How's this

for putting brains to work?

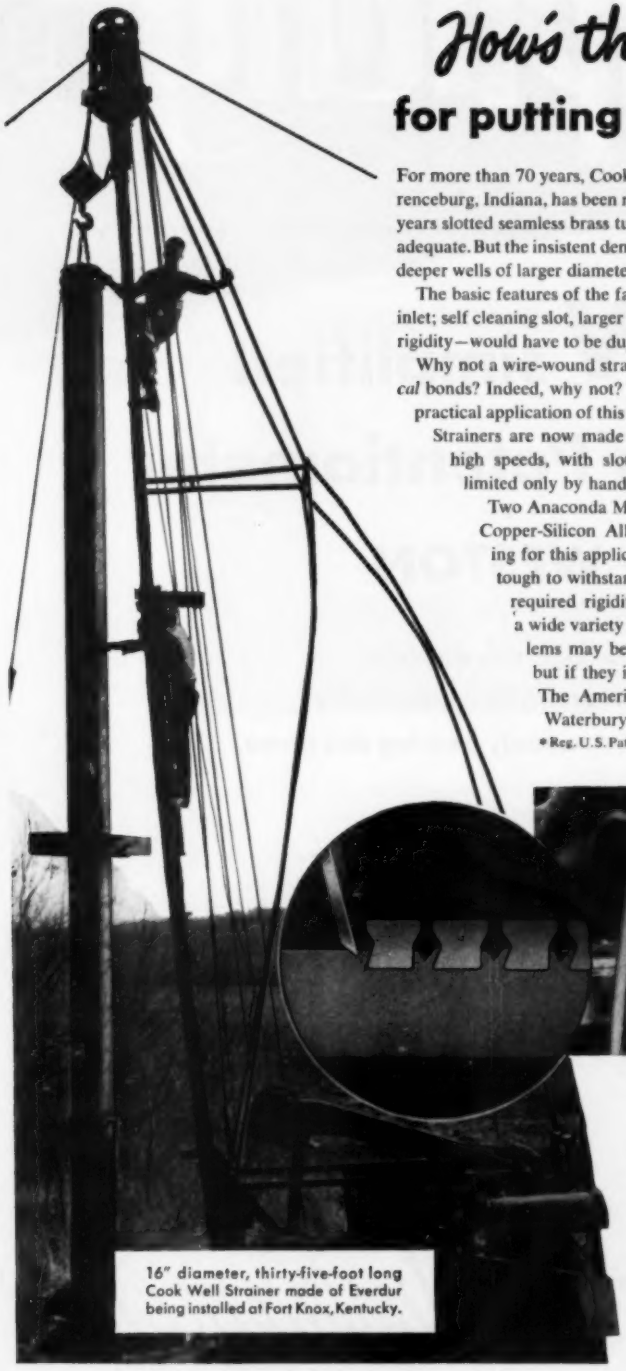
For more than 70 years, Cook Well Strainer Company, Inc., of Lawrenceburg, Indiana, has been making well strainers. For many of these years slotted seamless brass tubes, up to 12" diameter, proved wholly adequate. But the insistent demand for more and more water called for deeper wells of larger diameter—and strainers to meet the new needs.

The basic features of the famously successful tube strainer—direct inlet; self cleaning slot, larger inside than outside; one metal; strength; rigidity—would have to be duplicated in larger diameters.

Why not a wire-wound strainer with automatically-made *mechanical* bonds? Indeed, why not? The illustrations on this page show the practical application of this ingenious idea. Cook Wire-Wound Well Strainers are now made in sizes up to 40" inside diameter—at high speeds, with slot widths readily variable, and lengths limited only by handling facilities.

Two Anaconda Metals, Red Brass-24 and Everdur*-1010 Copper-Silicon Alloy, have proved themselves outstanding for this application. Both machine readily, are plenty tough to withstand upsetting, contribute strength for the required rigidity, and provide excellent resistance to a wide variety of corrosive ground waters. Your problems may be different, mechanically or chemically, but if they involve copper, brass or bronze, call on The American Brass Company, General Offices, Waterbury 20, Connecticut. 9202

*Reg. U.S. Pat. Off.



16" diameter, thirty-five-foot long Cook Well Strainer made of Everdur being installed at Fort Knox, Kentucky.

As the supporting skeleton of bars revolves in this winding machine, each bar is machine-notched ahead of the spirally wound wire (see circle illustration). This wire is a special drawn Anaconda Shape of modified keystone cross-section. A circular form tool then displaces the metal on one side of the V-groove into the dovetail section of the wire, locking it securely.

the name to remember

ANACONDA

COPPER, BRASS & BRONZE

Simplicity

NEW simplified Recording Potentiometer by WESTON

built to the same high standards of accuracy . . . sensitivity . . . durability as all instruments bearing this name.

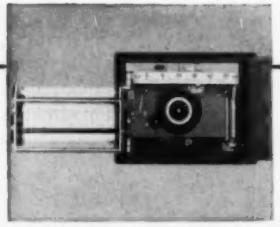


Chart frame swings out full 180° on straight pivots, chart remaining in time sequence. Charts easily installed in matter of seconds.

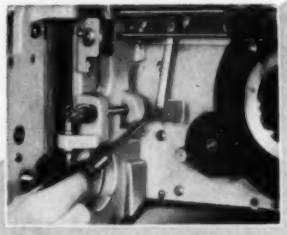
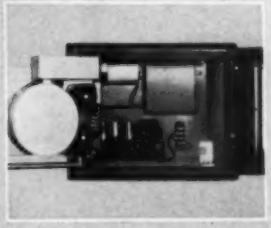


Chart speeds changed by simple screwdriver adjustment. Ranges quickly changed, too, by simply inserting correct range standard.



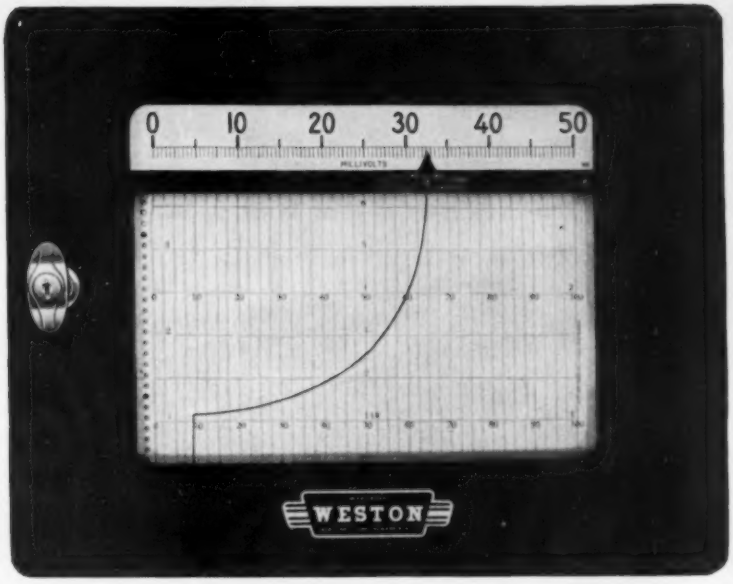
Note extreme simplicity both mechanical and electrical; as well as complete accessibility for quick maintenance and servicing.

WESTON 9128

WESTON *Instruments*

INDICATE . . . RECORD . . . CONTROL

The Regional



With this new high-speed Recording Potentiometer WESTON sets a new pattern for sound, simplified design . . . for simplicity and economy of maintenance . . . and for sustained high accuracy and sensitivity. With fewer components . . . with all assemblies greatly simplified and quickly interchangeable . . . with all adjustments including range changes made quickly on-the-line . . . with new compactness, ruggedness, and sustained high accuracy . . . this modern instrument will cut costs, and eliminate headaches wherever instrumentation is involved. You will want all the facts. Ask your local WESTON Representative, or write direct . . . WESTON Electrical Instrument Corporation, 617 Frelinghuysen Avenue, Newark 5, New Jersey . . . *manufacturers of Weston and Tag Instruments.*

Chart installation is Simpler — with new accessibility, and no loose parts to handle, chart can be installed in half the usual time. The chart drive has been simplified, made more positive, too.

Chart speed changes are Simpler — exclusive multi-speed chart drive permits instant selection of five different speeds with ordinary screwdriver. Speeds doubled or quadrupled by two simple gear changes.

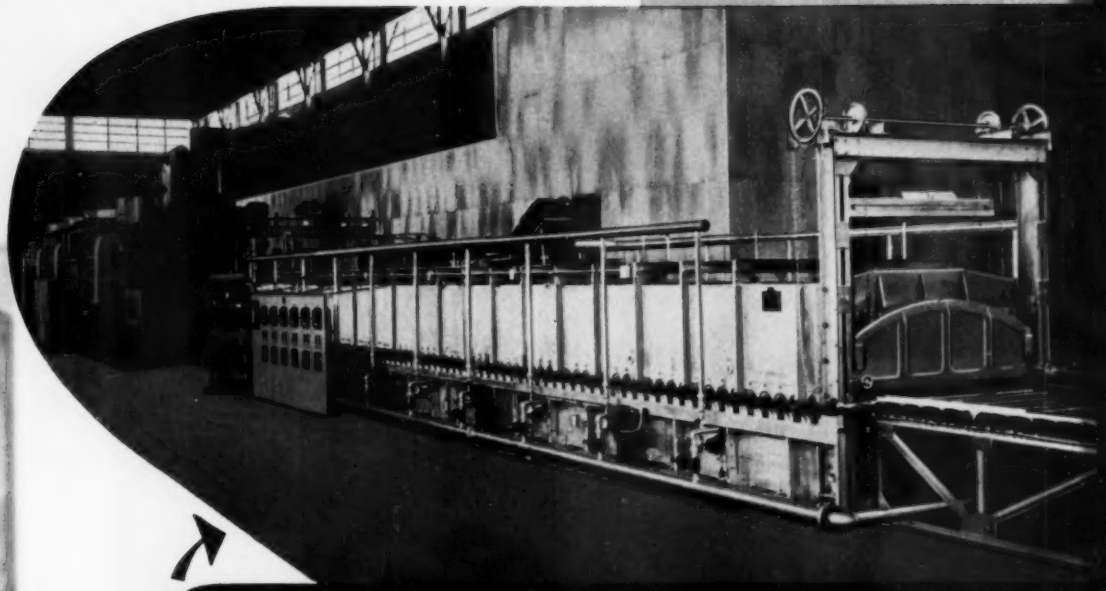
Changing ranges is Simpler — you just insert correct range standard and tighten with screwdriver. Reference junction compensation changed in like manner. *No soldered connections used.* Universal slide wire needs no changing.

Pen and carriage are Simpler — pen quickly, easily filled without removal, or taking instrument out of service. Pen won't clog, never pumps or syphons-off, needs no priming after initial starting. One-piece pen carriage has oil-less bearings and is driven by woven stainless steel cable.

New Simplified ruggedness—all parts amply proportioned for strength and rigidity, to maintain mechanical alignment under tough usage.

All maintenance is Simpler — plug-in type amplifier, for example, removed in a jiffy. Liberal use of oil-less bearings reduces lubrication problems. No on-the-job soldering required.

Continuous Roller-Hearth



Line approximately 260 ft. long,
12 ft. wide, 17 ft. high

for Plate

Line consists of Hardening Furnace
Tempering Furnace, Pressure Quench
and various charge and discharge tables.

Gas-Fired, Oil-Fired or Electrically Heated.

These lines are adaptable to other
products; e.g. Steel Bars.

Automatic oil quenches are available
for products requiring oil quenching.

EQUIPMENT CAN BE FURNISHED FOR ANY CAPACITY.

In addition to many lines installed during the second world war, installations in the past 18 months have been made and are in operation in the following plants:

Doehler-Jarvis Co.
Electric Autolite Co.
Florence Stove Co.
Kalamazoo Stove Co.
Metals Fabricating Co.
Rockwell Manufacturing Co.
Scaife Co.
Standard Steel Spring Co.
Newton Falls, Ohio Division
Williamson Heater Company

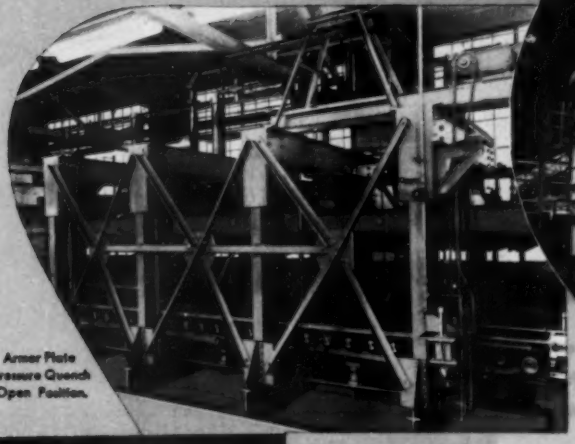
Heat Treating Lines for ARMOR PLATE

AND OTHER PRODUCTS

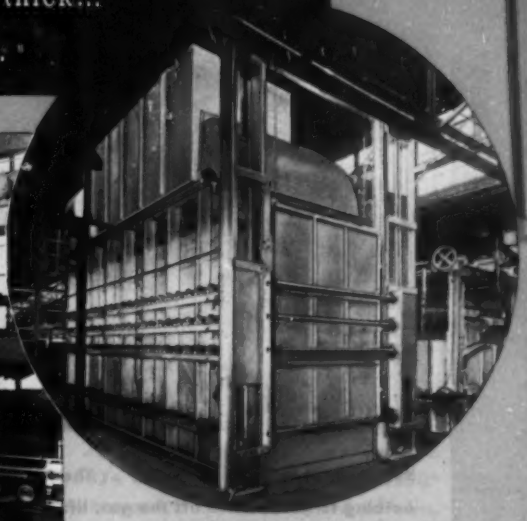
by DREVER

6' x 60' Roller-Hearth Hardening Furnace Discharge End — showing Elevating Discharge Table. Elevating Table feeds hot plate to press at variable levels.

up to 6 ft. wide, 18 ft. long, 4" thick...
Capacity 8000 lbs./hr.



Armor Plate Pressure Quench Open Position.



Four level Roller-Hearth Tempering Furnace.
Recirculated Air Heating.
Dimensions inside — 6' wide x 24' long x 7' high.
Capacity, 10,000 lbs/hour — temperature 1250°F.

Send your requirements to our competent and experienced staff of engineers.

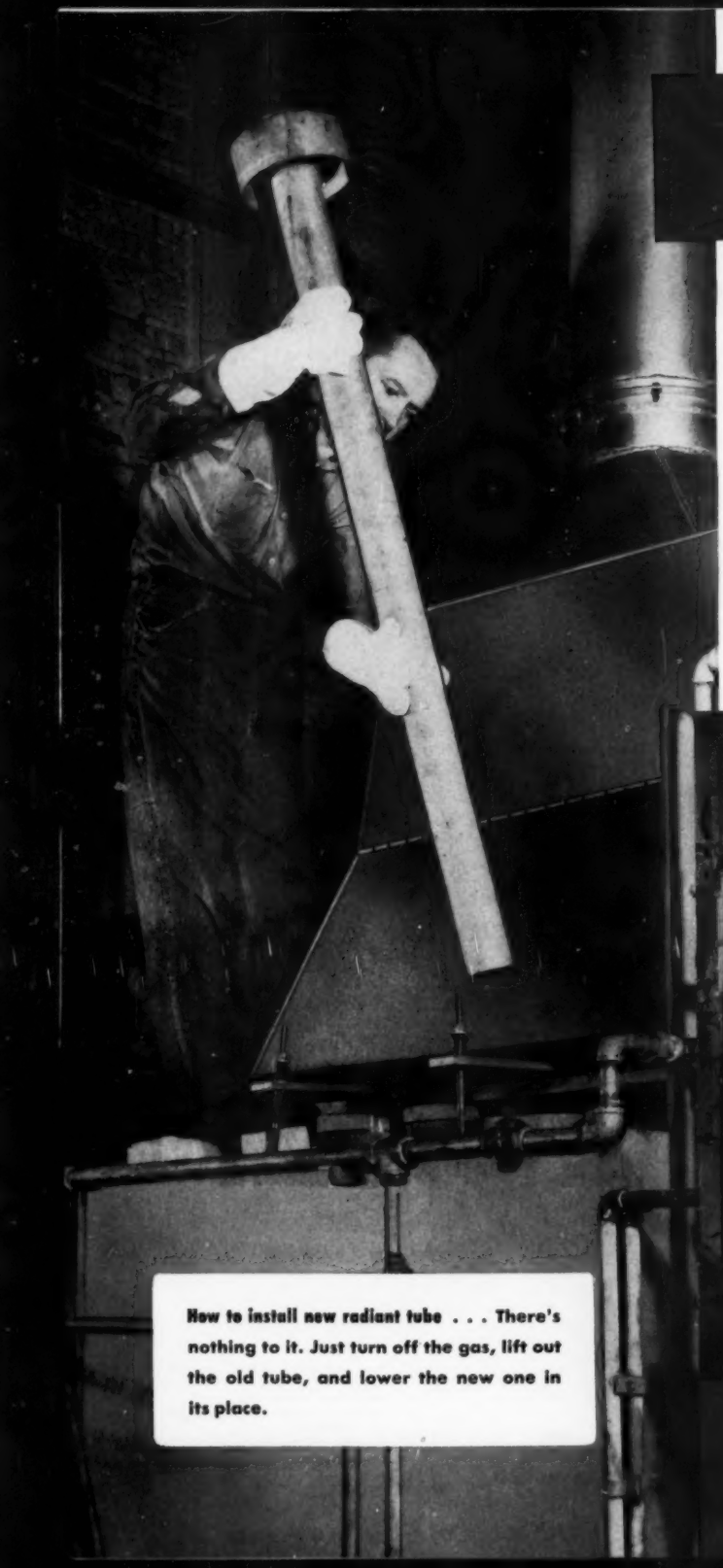
DREVER CO.

790 E. VENANGO ST., PHILADELPHIA 34, PA.

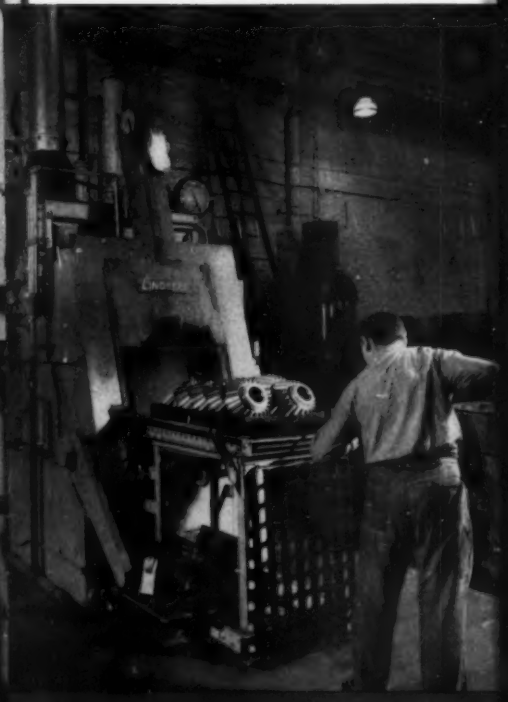
zip-zip . . . . . like in LINDBERG

Well, maybe not that fast . . . but it'll seem that fast if you've ever had to struggle around with the old type heavy radiant tubes. These new gas-fired, vertical tubes weigh only 29 pounds . . . almost as light as a razor blade by comparison.

All you do is turn off the gas, get on top the furnace, lift out the old tube, lower a new one in its place . . . and that's it.



How to install new radiant tube . . . There's nothing to it. Just turn off the gas, lift out the old tube, and lower the new one in its place.



. change radiant tubes blades in your razor!

CARBONITRIDING FURNACES

Simple, isn't it? No furnace cooling necessary . . . no extended down time . . . no clumsy plugs to unbolt . . . no squirming around inside the furnace.

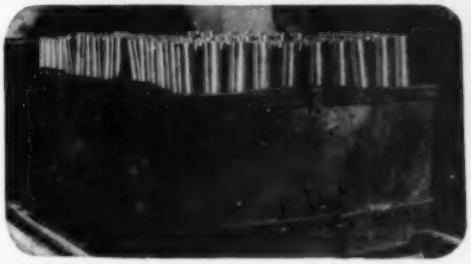
But ease of maintenance is only one of the advantages offered by this amazing Lindberg Carbonitriding Furnace. Check these important construction features:

Quench tank pit unnecessary . . . Your Lindberg Carbonitriding Furnace includes a built-in pitless quench tank . . . thus you avoid costly excavation and piping. But more important, this built-in quench tank minimizes distortion . . . quenching takes place within the furnace structure, by means of a vertically operated elevator. Heated charges are never exposed to the air . . . as would be the case if work had to be transferred from the heating chamber to a separate quench tank. Uniform case depth is assured because each charge automatically remains at heat the same length of time.

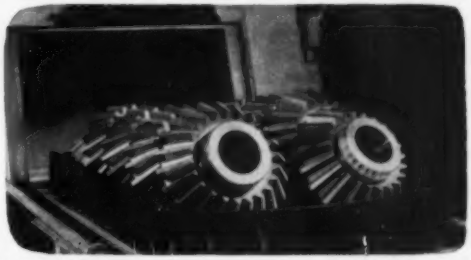
Preheat and purge chamber . . . Prior to entering the furnace heating chamber, work enters area immediately above built-in quench tank. Here, work is preheated . . . this reduces drastic temperature change when work enters heating chamber. Also, the work is completely purged while it is preheating.

Many furnaces in one . . . Furnace atmosphere is provided by Lindberg "Hyen" endothermic atmosphere generator that is easily adjustable to supply different atmospheres not only for carbonitriding, but also for carburizing, carbon restoration, bright hardening or annealing and normalizing. For annealing and normalizing the heated charge cools in the same chamber used for preheating and purging.

For additional information write your nearest Lindberg office . . . or Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.



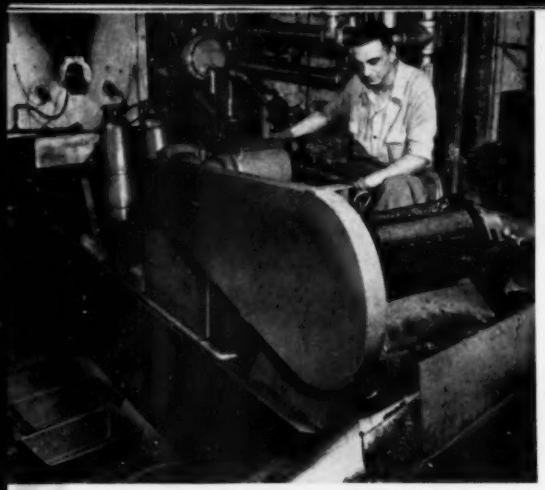
CARBONITRIDING . . . Specifications called for .023 to .025" case on these low carbon seamless tubes. The charge weighed 450 lbs., and required 1¾ hours.



CARBURIZING . . . 450 lbs. of these bevelled gears, SAE 1020, required three hours total time to obtain a .032" depth.

ANNEALING . . . These SAE 1045 gear blanks were annealed to 174 Brinell. Temperature was 1550° F., time 1½ hours. The charge weighed 350 lbs. Cooling was in atmosphere.

LINDBERG **FURNACES**



LESS DRAG-OUT... NO SLUDGE. This continuous shaker hearth furnace heat-treats parts at 1,525 F and quenches them in oil controlled between 120 F and 130 F. With the oil formerly used, drag-out was excessive and sludging a constant problem. By switching to Sun Quenching Oil Light, the company reduced drag-out appreciably and eliminated sludging altogether.

SURFACE SPOTTING ELIMINATED. The oil used formerly by this company gave quenched parts a troutlike appearance. It also left traces of smut. Ever since the switch to Sun Quenching Oil Light, parts have come out clean and a shiny blue-black color. Among the materials used by this screw manufacturing plant are: SAE 4037, 3135, 4137, 6850 steels.

PRODUCTION IMPROVED, COSTS CUT 40% BY SWITCH TO SUN QUENCHING OIL LIGHT

A large New England company manufacturing socket screws and related items was using an expensive oil for quenching. Nevertheless, results were poor. Drag-out was excessive. Heavy sludge deposits accumulated in the tank. Instead of coming out shining and blue-black in color, parts were dirty, and speckled with brownish spots. Obnoxious oil vapors bothered the operators.

The company asked a Sun representative for suggestions and on his advice filled the system with Sun Quenching Oil Light on a test basis: then, after five months' trial, adopted it. Oil costs have dropped 40 percent—an annual saving of $1,200. Drag-out is less —with lower oil consumption resulting. Quenched parts come out a clean blue-black. Because of the natural detergency of this product, the system remains clean at all times. Odors are no longer a problem.

Sun Quenching Oils give consistently uniform results. They drain off rapidly, keeping drag-out to a minimum. They do not thicken up and lose their quenching speed. Under normal operating conditions, they do not form sludge and need never be replaced. *Sun Quenching Oils, although far less expensive than highly compounded oils, meet the requirements of 95 percent of all quenching operations.*

SUN OIL COMPANY, Dept. MP-7, Philadelphia 3, Pa.
I am having problems possibly caused by an inadequate quenching oil.

☐ Please have a Sun representative contact me.

☐ Please send me informative booklet, "Sun Quenching Oils."

Name_____

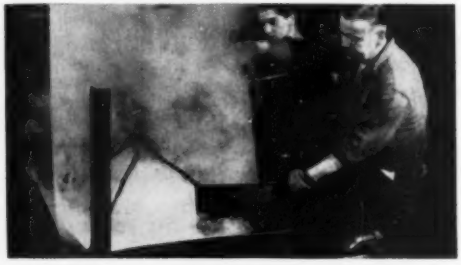
Title_____

Company_____

Street_____

City_____ Zone____ State_____

TECHNICAL ASSISTANCE AVAILABLE. Sun's engineers are at your service for consultation on quenching-oil matters. It will pay you to utilize the experience they have gained solving a wide variety of problems in other plants.



NO OBNOXIOUS VAPOR ODORS. With the former oil, objectionable odors raised a serious morale problem. The odor of Sun Quenching Oil Light is not unpleasant. A big improvement has therefore resulted in working conditions.

SUN INDUSTRIAL PRODUCTS

SUN OIL COMPANY, PHILADELPHIA 3, PA. • SUN OIL COMPANY, LTD., TORONTO AND MONTREAL

SUNOCO®

Engineering Digest

OF NEW PRODUCTS

FORGING PRESSES: Development of an improved line of high-speed forging presses has been announced by the E. W. Bliss Co. Available in capacities from 300 to 4000 tons, the new line features a heavy-duty air-friction clutch and an air-release spring-set brake, both mounted on a full eccentric main shaft. The welded steel frame is designed with the main stress members located immediately adjacent to either side of the die seat

and extending from the bottom of the bed to the top of the crown. These members have unusually heavy sections to keep the elongation of frame to a minimum when load is applied to the press. A heavy plate, integral with the two front gibs, is bolted securely to the main stress-carrying members. This plate, in addition to massive frame-tying members in the rear of the press, opposes the inward deflection of frame toward the slide ways.

For further information circle No. 1 on literature request card on p. 32B.

LEADED STEELS: LaSalle Steel Co. has announced two new leaded steels. "Super La-Led", an improved free-machining openhearth lead-bearing steel in cold finished bars, will machine about 80% faster than B1113. Where corrosion is not a factor and where brass has previously been selected primarily for its machinability, this steel will usually produce a comparable part at lower cost. Leaded TS4140 machines one-third faster than the nonleaded alloy, with no change in hardenability and heat treating characteristics. The sole purpose of adding lead is to promote machinability.

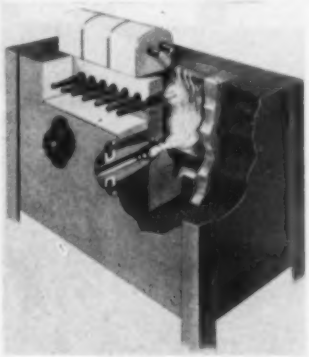
For further information circle No. 2 on literature request card on p. 32B.

RADIOGRAPHY: The McElroy-McNutt technique of "hot radiography" permits the taking of X-ray photographs of large pipes, valves, and similar units at temperatures as high as 1200° F. This process, licensed by Sam Tour & Co., Inc., has been applied with considerable success to the inspection of partially completed welds on hot sections of pipe to check for possible welding defects. With ordinary radiographic technique, before the film can be placed on the weld, the pipe section must be cooled down to about 100° F. With certain types of alloys, this cooling

must be preceded by post-heating the weld to relieve stresses. Because of the lengthy cooling period involved, the usual practice has been to complete the weld before inspecting it. However, hot radiography, which can be accomplished on a hot pipe, makes it practical to interrupt the welding operation to inspect the weld root where most flaws occur. This technique, therefore, saves the many manhours of heating and controlled cooling that were formerly required before the weld could be inspected. Additional time is saved because, if defects are found, it is necessary to chip away only a partially-completed weld, rather than a finished weld.

For further information circle No. 3 on literature request card on p. 32B.

TOOL FURNACE: A new forging furnace to heat high speed and alloy chisels for both forging and hardening, and to provide true "cold shank" heating has been announced by the Delaware Tool Steel Corp. A new principle, which confines heat to the



chisel point, prevents loss of temper in the shank during tool redressing. Thus, shank breakage is virtually eliminated in tool use. The furnace provides fast, uniform heating controllable between 1200 and 2800° F.

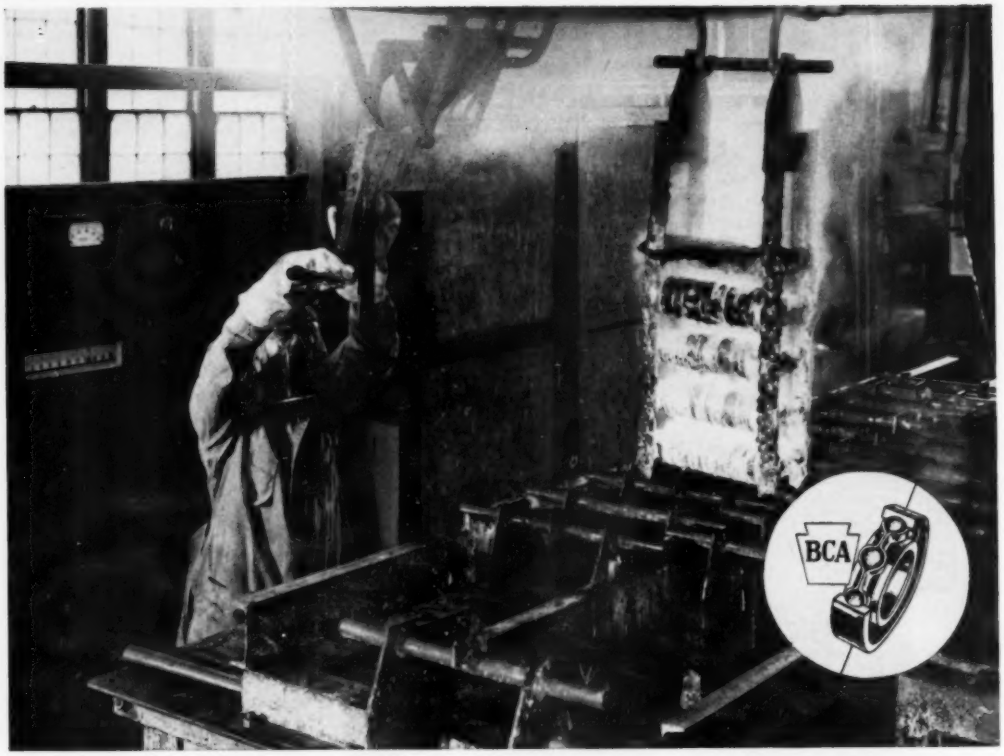
For further information circle No. 4 on literature request card on p. 32B.

WELDING FLUX: A new welding flux that is equally effective as paste or powder has been announced by All-State Welding Alloys Co. The new product was developed as the special flux for All-State's new X-2S and X-43S aluminum rods, and is also satisfactory for gas welding of stainless steel.

For further information circle No. 5 on literature request card on p. 32B.

MECHANICAL CLEANING: Pangborn Corp. has announced its new airless Rotoblast barrel, available in 6 and 12-cu.ft. capacities. A newly de-

signed work conveyor prevents passage of wire or chill nails into the track of the chain where operation could be affected. When the barrel



Conversion to liquid carburizing saves 6,000 sq. ft. of space . . . triples productive capacity

JUST TWO compact, liquid carburizing units have replaced *twenty-five* pack carburizing furnaces at Bearings Co. of America, Lancaster, Pa. These space-saving units require 6,000 sq. ft. less floor area and have increased production by almost 300%! Conveyorized bath operation reduces tedious manual handling . . . produces deep cases of exceptional uniformity on ball bearing races.

More and more plants are converting to liquid carburizing for high quality case hardening at low cost. They're finding that this efficient process reduces the danger of overheating by permitting accurate control of carburizing temperatures . . . greatly lessens the problem of distortion . . . and provides fast, uniform heating that insures cases of maximum uniformity—even when parts have extremely irregular sections!

Perhaps your plant can profit by converting to a molten salt bath process. Get in touch with your nearest Du Pont office today. Our technical representatives will be glad to study your problem and help in the selection of materials and the planning and layout of equipment. E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Department, Wilmington 98, Delaware.

• • •

There's a Du Pont molten salt bath for every heat treating need. Sodium Cyanide, Accelerated Salt WS,* and Carburizing Salt—for shallow, medium and deep cases—are just three of the Du Pont heat treating materials that can mean top production and maximum economy for your plant.

**Water Soluble*

DU PONT
CYANIDES and SALTS
for STEEL TREATING

DU PONT
REG. U.S. PAT. OFF.

150th Anniversary

Better Things for Better Living . . . through Chemistry

ELECTROCHEMICALS DEPT. DISTRICT OFFICES:
Boston, Charlotte, Chicago, Cincinnati, Cleveland, Detroit, El Monte (California), New York, Philadelphia

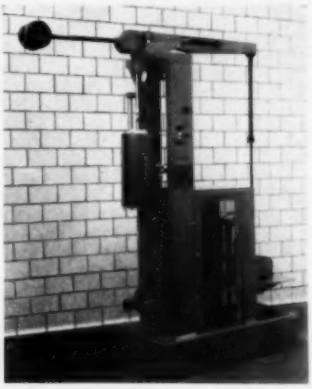
is operating, the conveyor travels upward to tumble the castings. After the cleaning operation, direction of the conveyor is reversed and the load is discharged into the work loader. An automatic throw-out torque arm disengages the barrel drive in case of jams. It works in both loading and unloading directions. An abrasive-tight door and housing retain abrasive within the machine and permit economical use of new-type abrasives.
For further information circle No. 6 on literature request card on p. 32B.

WELDING OVEN: Despatch Oven Co. has announced a new oven specifically for welding applications, to eliminate moisture absorption in low-hydrogen and other coated electrodes. Gravity convected heat and economi-

cal storage are provided at the point of use. This system cuts down rework costs, underbead cracking and rough welds. The oven is square and 10 separate compartments hold 250 lb. of electrodes.
For further information circle No. 7 on literature request card on p. 32B.

NONFERROUS TUBE MILLS: The Yoder Co. has developed a machine for producing electrically welded tubing of practically all aluminum alloys available in coiled sheet form, copper alloys, various brasses, nickel, Monel, Inconel and stainless steels. At present the company is offering three sizes of mills which have a total capacity range of ¾ to 8 in. diameter, on metal thicknesses ranging from 0.025 to 0.140 in. Welding speeds of 50 to 90 ft. per min. are practical. This represents a very great increase over previous methods of welding these alloys.
For further information circle No. 8 on literature request card on p. 32B.

HIGH-TEMPERATURE TESTING: A new lever-arm creep testing machine of 12,000-lb. capacity has been developed by Heppenstall Co. and is being manufactured by Arcweld Manufacturing Co., for use in testing alloys used in high-temperature applications. One of several features of the machine is a power-operated lifting mechanism for the weights used for loading specimens. During testing, the lifting platform automatically positions itself about ½ in. below the weight pan so that the



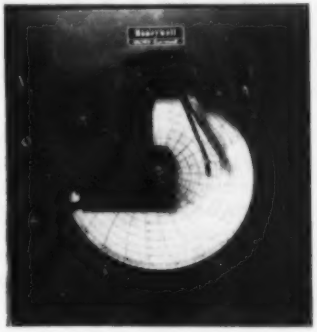
shock of dropping weights is minimized when the specimen breaks in stress-rupture tests. For testing at temperatures up to 1800° F. an exceptionally large furnace with three heating zones is provided. This hastens attainment of uniform temperatures over the gage length of specimens. Temperatures in the three zones can be individually regulated from the control panel. To simplify vertical adjustment, the furnace is counterbalanced and a position-indicating scale is provided. A locking arrangement prevents shifting of the furnace during tests.
For further information circle No. 9 on literature request card on p. 32B.

CLEANER: A new, heavy-duty type of steam cleaning machine for general industrial use has been announced by Topper Equipment Co. This Circo

cleaner (model 120) has a fully automatic, safety protected system which enables one-man operation while at the same time accelerates the cleaning process. At the snap of a switch a spark is generated which ignites the burner and puts the machine in action. From this point on, fully automatic controls maintain the operation at its peak, thus eliminating time-consuming adjustments. A mechanical outside safety valve is provided as a check on the electrical limit switch and by-pass valve. Heating coils are protected by a special control which stops the entire unit should the water supply fail or become inadequate.
For further information circle No. 10 on literature request card on p. 32B.

CHROMIUM PLATING: United Chromium's "Self-Regulating High-Speed" chromium plating solutions have been found superior to ordinary solutions in regard to effect on fatigue strength of plated 4130 steel. When this steel was chromium plated from an ordinary solution, fatigue strength was decreased by about 25%. The decrease was 8 to 15% when SRHS solutions were used.
For further information circle No. 11 on literature request card on p. 32B.

TIME-TEMPERATURE CONTROL: An electronically operated circular chart controller which can control industrial processes according to predetermined time-temperature sched-



ules has been developed by Minneapolis-Honeywell Regulator Co. This instrument combines, within a single case, measurement and recording on a 12-in. chart, automatic positioning of the set point index as directed by a transparent program cam, and automatic program control of the variable.
For further information circle No. 12 on literature request card on p. 32B.

COLD HEADING DIE STEEL: Allegheny Ludlum has introduced a higher alloy steel that can be water hardened exactly the same as the straight

How to S·T·R·E·T·C·H scarce alloying elements

Take nickel or molybdenum, for instance. Of all the important elements used in constructional alloy steels, none is more critical than these two. The fact is, this country hasn't nearly enough of either of these elements to meet current demands. And there is little chance that the situation will improve appreciably for many months to come.

But there is one way that the available stock of nickel and molybdenum can be stretched. Boron, of which we have an ample supply, can replace several hundred times its own weight in other hardening alloys in parts that are liquid-quenched and tempered. It does not completely eliminate the need for these alloys, but it does make them go considerably further.

Boron increases hardenability; that is, it increases the depth to which the steel will harden, provided the section size and method of heat treatment are such as to insure an effective quench. And only a few thousandths of 1 pct does the job. Boron-treated steels usually require more exacting temperature control for heat-treatment than ordinary high-alloy steels, but aside from this they present no special problems. As far as workability is concerned, the cold- and hot-working properties of boron steels are about equal to those of ordinary alloy steels, and in some cases have been found superior. Machinability of boron steels is also improved, because of their lower alloy content.

Bethlehem manufactures boron steels in addition to regular alloy grades, special and carbon steels. If you would like information on proper analysis or heat-treatment of steel for any purpose, our metallurgists will be glad to help. Write giving complete details.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

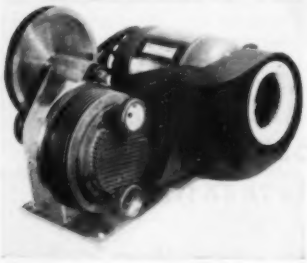
On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM ALLOY STEELS

BETHLEHEM STEEL

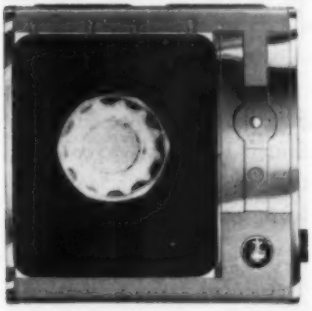
carbon or carbon-vanadium steels formerly used for cold-heading dies but has greater wear resistance. Repeated production runs indicate a die life two or four times greater than for steels available in the past.
For further information circle No. 13 on literature request card on p. 32B.

ABRASIVE SHOT TESTING: The Precision Shot Co. has developed an abrasive shot and grit testing unit which subjects the shot or grit particles to repeated impact in a manner similar to that in production shot blasting machines. The useful life of the different shot samples is indicated



by screening the samples through standard sieves after a standard length of time in the machine. The time required by the machine to test a sample of conventional chilled iron shot is less than 1 min. Weighing, loading, unloading and screening require about 5 min.
For further information circle No. 14 on literature request card on p. 32B.

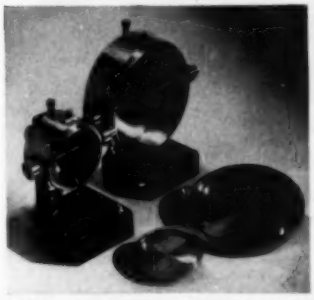
X-RAY ILLUMINATOR: The new Keleket high-intensity illuminator makes radiographs of the thickest structures plainly visible. A full



14 x 17 in. viewing surface permits inspection of large films; critical examination of small areas is accomplished before a 3-in. spot of four times the over-all intensity. This intense illumination permits maximum visualization and evaluation of obscure details, even in films with a density exceeding 4.5.
For further information circle No. 15 on literature request card on p. 32B

MELTING FURNACE: Recently the Detroit Electric Furnace Div. introduced its redesigned electric melting furnace for educational and experimental use and small production. Known as the type GMS, this furnace is used to produce quality melts of alloy iron, tool steel and stainless steel. It is specially designed for speed and uniformity of melts for limited production. It has a new rocking controller, which makes the furnace more completely adjustable in operation and easier to manipulate. Maximum length of the electrode is 42 in. The furnace is rated at 60 lb. capacity and operates at 30 kw.
For further information circle No. 16 on literature request card on p. 32B.

X-RAY CAMERAS: Two new X-ray diffraction powder cameras have been announced by North American Philips Co., Inc. Available in two sizes, 114.59 and 57.3-mm. diameters, these new cameras will record up to 17



Angstrom spacings with copper radiation, with low air scatter and unusually clear patterns in the forward reflection region. The cameras can be readily adjusted to fit most conventional camera tracks.
For further information circle No. 17 on literature request card on p. 32B.

SURFACE-RESISTANCE INDICATOR: A portable surface-resistance indicator, designed to help produce a better resistance welding bond by providing a rapid and accurate measurement of the resistance between pieces of metal to be welded, has been announced by the Special Products Div. of the General Electric Co. The new device supplies a simple check on pre-welding cleaning processes, upon which the surface resistance of the metal depends. Small changes in concentration or slight

ETOLIZING

. . . a new plating process with improved corrosion resisting properties — for metal powder parts

ETOLIZING is a plating process that has been developed in our laboratory. It offers excellent resistance to corrosion for metal powder parts.

Since the technique for plating metal powder parts varies with each type of material, we suggest that you write us in detail as to your requirements, mentioning type of metal powder used, etc.

Our laboratory is available to work with you on our **ETOLIZING** process. Furthermore, there is no obligation, so why not write to us today?

●

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NEW YORK 17, N. Y.

ROLOCK

FABRICATED ALLOYS

AN ASSEMBLY THAT *"Gives a Lift"* TO AN IMPORTANT HEAT TREATING JOB

Four sets of these Stacking Furnace Baskets were custom-fabricated by Rolock to fit pit-type furnaces built by Hevi Duty Electric Company. Photo at left shows bottom grid, mesh disc, lift straps and fastening keys. Photo at right shows complete assembly ready for furnace.

They are used by a nationally known manufacturer for hardening at 1850° F. Material of basket is type 330 stainless steel. Size, each basket 28" I.D. x 12¾" high. To facilitate handling in and out of the furnace the baskets are securely fastened together with alloy lift straps and keys. Note fabricated bottom grid and mesh disc. All welding is of the highest quality.

Rolock equipment is engineered to suit the specific job... for maximum strength... for as high ratio of load to weight as safety permits ... for handling convenience... and for low hour-cost through extended service life. Our engineering department likes to solve problems. Tell us about yours!

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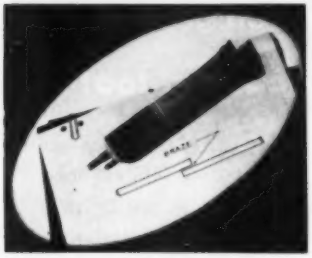
ROLOCK INC. · 1222 KINGS HIGHWAY, FAIRFIELD, CONN.

JOB ENGINEERED for better work
Easier Operation, Lower Cost

contamination of cleaning solutions cause surface resistance to vary widely, and ultimately result in an unsatisfactory resistance welding bond. In operation, the sample pieces of metal to be welded are placed between the jaws of the sample holder and subjected to the desired pressure. The surface resistance between the metal samples is indicated on the microhmmeter. The entire operation can be completed in a matter of seconds.

For further information circle No. 18 on literature request card on p. 32B

BRAZING PASTE: Phos-Copper, a free-flowing brazing alloy with a low melting point for brazing operations on copper and copper alloys, is available in paste form from Westinghouse Electric Corp. The new brazing paste is finely powdered alloy suspended in petroleum jelly. A small amount of this paste placed between



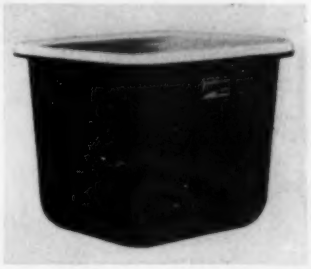
the pieces being joined takes the place of a brazing rod, and the joint need only be heated until the brazing filler metal flows. It is designed for resistance brazing where it can be conveniently pre-placed and is packaged in collapsible one-pound tubes and in 5 and 30-lb. cans.

For further information circle No. 19 on literature request card on p. 32B.

GAS-OIL BURNER: The new Ra-Diant combination gas-oil burner is designed to support substantially complete combustion (11½% CO_2 Orsat). The burner will light instantaneously, without preheating, because a charge of highly combustible gas is retained within the porous structure of the liner from previous usage. The burner will burn oil of grades 1 through 6, and is specially adapted to burn natural gas and high-Btu. mixed gases.

For further information circle No. 20 on literature request card on p. 32B.

FINISHING TANK: MacDermid Inc. has recently introduced a new idea in finishing room tanks made of laminated fiberglas, the same type material at present being featured in "glass" boats, furniture, fishing rods, and experimental automobile bodies. This new material is durable, lightweight, has high impact resistance, and the tanks are highly resistant to



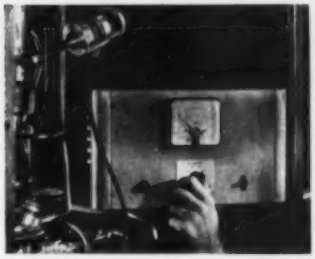
chemical attack inside as well as outside. They are nonconductive and can withstand freezing as well as boiling temperatures.

For further information circle No. 21 on literature request card on p. 32B.

BLACKENING: A new two-bath method for blackening ferrous alloys has been perfected by The Swift Industrial Chemical Co. Swift Nu-Black, as the method is called, is reported to be effective over a wide temperature range, creating a black surface of uniform density without dimensional change in the piece.

For further information circle No. 22 on literature request card on p. 32B.

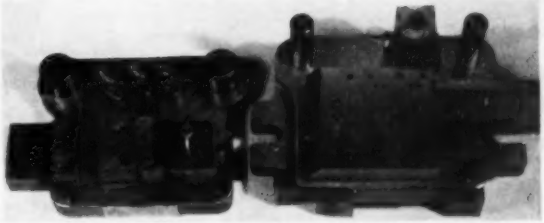
VACUUM GAUGE: A new vacuum gauge which covers a range of 8,000,000 to 1 on a single meter from a single pick-up has just been announced by Distillation Products Industries. This new gauge can be used to read vacuums from 0.50 mm. to 10^{-7} mm. Hg. The all-metal pick-



up tube which handles this range works on the glow discharge principle. Having no filament to burn out, the new tube can be operated at full atmosphere without damage.

For further information circle No. 23 on literature request card on p. 32B.

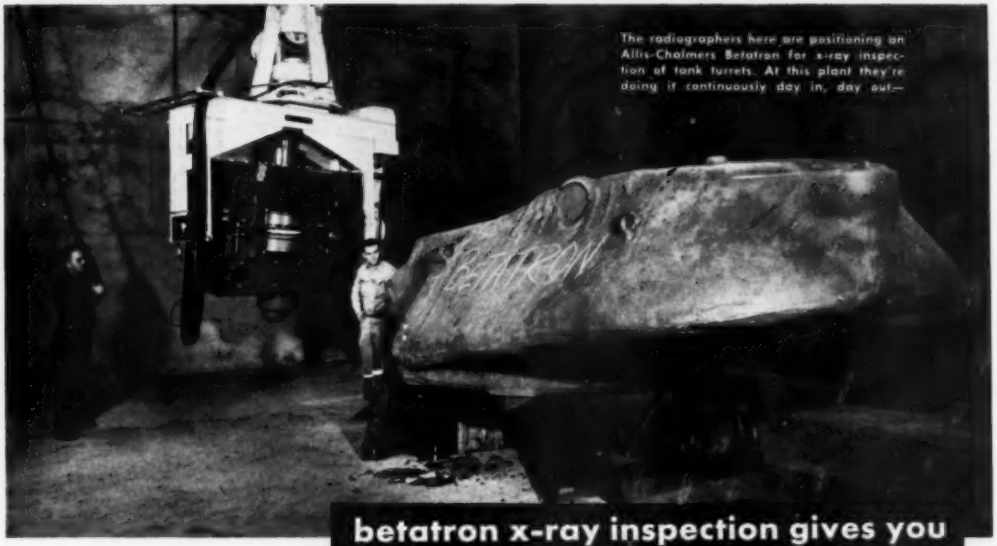
350,000 Wing Nuts from Ziv's Hargus Tool Steel Die...



This progressive pierce–blank–form die is ZIV'S HARGUS tool steel. From it were made 350,000 wing nuts with a production per grind of 87,500 pieces. HARGUS, an oil-hardening, non-deforming tool steel, was selected, in preference to other types of steels, for this intricate die because past experience with HARGUS had convinced the user that he could rely on its serviceability. The die shown costs approximately $800.00. Yours may be more or less expensive. In any case, it will pay you to use HARGUS.

ESTABLISHED 1911
ZIV STEEL & WIRE CO.
2945 W. HARRISON STREET • CHICAGO 12, ILL

BRANCHES
Detroit, Mich., Milwaukee, Wis., Toledo, Ohio, St. Louis, Mo., Indianapolis, Ind., Eagle River, Mich.



The radiographers here are positioning an Allis-Chalmers Betatron for x-ray inspection of tank turrets. At this plant they're doing it continuously day in, day out—

betatron x-ray inspection gives you all this . . . and **dependability**, too!

speed — 22 million volt x-rays will penetrate 10 inches of steel in 5 minutes.

detail — Focal spot is so small (0.00003 sq. in.) that you get pin-point detail.

ease — No need for barium or lead-blocking agents to prevent "burning out" of thin sections.

economy — Fewer, faster radiographs means savings in man-hours, plant-hours, films.

Sure . . . x-ray inspection with 22,000,000 volts will detect flaws as small as 1/8" deep, or .002" wide, in steel 12" thick or more.

Sure . . . x-ray inspection with the betatron gives you all the other advantages listed at left.

But all that wouldn't mean a thing if you couldn't also depend on it to operate continuously. You can't run a heavy inspection schedule with a temperamental machine that's laid up for repairs more often than not.

The Allis-Chalmers Betatron has a proven record of dependability, supported by plenty of evidence . . . evidence accumulated over tens of thousands of hours of heavy-duty inspection in plants like the one above.

ALLIS-CHALMERS
Betatron
IS DISTRIBUTED AND SERVICED BY

Picker x-ray

The Allis-Chalmers Betatron is marketed, installed and serviced by Picker X-Ray Corporation. The far-flung sales and service network of this organization, the largest in the world devoted exclusively to x-ray, stands behind every machine. Somewhere on this map, there's a local Picker representative near you.

PICKER X-RAY CORPORATION
25 SO. BROADWAY • WHITE PLAINS, N. Y.

What's new — IN MANUFACTURERS' LITERATURE

24. Abrasive Wheels
Data folders give operating suggestions and recommended grades of abrasive wheels for stainless alloys, for finishing, semi-polishing and other applications. *Manhattan Rubber Div.*

25. Alloy Steel
16-page, pocket-size booklet, "Alloy Steels and How to Get the Most Out of Them", contains seven case histories selected from widely varied fields. *Republic Steel Corp.*

26. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

27. Aluminum Castings
24-page brochure gives tabular data on composition, mechanical properties and heat treatments of standard aluminum casting alloys. ASTM, SAE and Alcoa designations cross-referenced. *Apex Smelting Co.*

28. Aluminum Fasteners
8-page booklet on all types of aluminum fasteners. Also accessories and screw machine products. All are illustrated. *Aluminum Co. of America*

29. Aluminum Melting Flux
Data sheet on four fluxes for degassing and purifying aluminum alloys. *Atlantic Chemicals & Metals Co.*

30. Ammonia
20-page bulletin gives details on layout of ammonia installations for nitriding and carbonitriding. *Armour & Co.*

31. Analysis
16-page booklet explains the theory behind colorimetry, fluorometry and nephelometry and the operation of a new instrument combining all of these techniques. *Fisher Scientific Co.*

32. Annealing
Booklet on burner especially designed for annealing furnaces and other uses where flame impingement is not permissible. *Bloom Engineering Co., Inc.*

33. Annealing
7-page article, "Annealing Steel Cartridge Cases at Ekco Products", describes furnace practice and results. *Sunbeam Industrial Furnace Div.*

34. Anodizing Racks
Folder gives data on aluminum racks with copper hooks, insulated for any anodizing solution. *National Rack Co.*

35. Arc Welders
Illustrated booklets available on both A-C and D-C arc welders. Contain data and diagrams on construction and uses. *Westinghouse Electric Corp.*

36. Atmosphere Furnace
Illustrated bulletin describes new controlled atmosphere furnace. *Industrial Heating Equipment Co.*

37. Atmosphere Furnaces
Information on new gas-atmosphere high-production furnace for handling bright annealing of wire, strip and bar stock of copper and nonferrous copper alloys. *Holcroft & Co.*

38. Atmospheres
8-page Bulletin SC-155 discusses following controlled atmospheres: RX, DX, NX, HNX, AX, HX. Compositions, capacities, applications, effects on steel, schematic drawings of generators. *Surface Combustion Corp.*

39. Automatic Polishing
14-page, illustrated brochure describes automatic equipment for polishing, buffing and grinding. *Murray-Way*

40. Band Saw Blades
Bulletin on wavy-set and raker-set band saw blades. Standard specifications included. *Henry G. Thompson & Son*

41. Barrel Finishing
20-page bulletin describes use of burnishing materials and finishing barrels. Six steel burnishing shapes explained. *Abbott Ball Co.*

44. Beryllium Copper
Helpful engineering information contained in monthly beryllium copper bulletins. *Beryllium Corp.*

45. Blackening Compounds
Bulletin on blackening compounds (for ferrous alloys) which meet AMS specification 2485. *Swift Industrial Chemical Co.*

46. Blowers
Bulletin on new constant-pressure turbo blower and properly selected piping. *North American Manufacturing*

47. Brass, Free-Cutting
Illustrated, 24-page publication, B-14, on rods for screw-machine use includes physical constants and properties of 46 free-cutting and general-purpose rods. *American Brass Co.*

48. Brazing
24-page bulletin 20 on advantages of Easy-Flo silver brazing alloy, with information about joint design and fast production methods. *Handy & Harman*

265. Surface Grinding

Although directed primarily to production men, "ABC of Surface Grinding"* will prove interesting and enlightening to any engineer concerned with the precision finishing of metal surfaces.

Surface grinders of today, with their finger-tip controls and high-speed, smooth hydraulic table traverses, have little resemblance to their counterparts of 25 years ago. Thus an understanding of how they operate and of the many short cuts connected with their use will help all concerned to do a better job.

This compact, 92-page handbook comprises three sections: Grinding know-how, wheel selection, and trouble shooting. The first covers the five general types of surface grinding machines—horizontal and vertical spindle reciprocating table units, horizontal and vertical spindle rotary table machines, and face grinders.

Considerable space is given to the subject of magnetic chucks, their care and maintenance. Numerous little tricks of the trade have come to light in the most efficient use of these chucks, as they have in practically all phases of operation of surface grinding machines. These are pointed up in simple language and should suggest worthwhile changes in practice to many grinding departments.

The matter of wheel selection is examined at some length, with basic information itemized on how a grinding wheel cuts and the composition of various types of wheels.

Common troubles with wheels, such as glazing, loading, chatter marks or burning of the work, and out-of-square or out-of-parallel conditions of the work are reviewed and corrective measures suggested.

Throughout the text appear 35 unusually clear and "close-up" halftones of machines in action which aid greatly in clarifying the why and how of good surface grinding.

*Published by Norton Co. Copies are available at no charge to readers of Metal Progress who circle No. 265 on literature request card, page 32B.

42. Barrel Finishing
22-page booklet J-7 gives up-to-date facts and figures on barrel finishing, tells how single-unit installation may yield savings up to 95% on various types of parts. *Almco Div.*

43. Bearing Failures
12-page bulletin 146 outlines basic steps for prevention of common babbitted bearing failures—choice of metal, pouring practice, in-service maintenance. *Federated Metals Div.*

49. Burners
Bulletin 1220-5 describes tempered flame burners for controlled heating and cooling cycles. *Bloom Engineering*

50. Burners
Bulletin on combination gas and oil burner with high rate of combustion. *Ra-Diant Heat Refractories Sales Co.*

51. Carbon and Graphite
New 20-page catalog describes and illustrates products made of carbon and

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graphite from porous to impervious for applications in metallurgical, mechanical, electrical, chemical and process fields. *National Carbon Co.*

52. Carbon Control

Catalog T-623 describes the Microcarb control system that continuously measures the active carbon in the furnace atmosphere during heat treatment. *Leeds & Northrup Co.*

53. Carbon Test

Illustrated data discusses melter's test for estimating carbon content of molten steel in 40 sec. *Harry W. Dietert*

54. Carburizing

Case history and job data on localized carburizing of sewing machine parts. *Ipsen Industries, Inc.*

55. Carburizing Baths

Bulletin contains charts of relative case penetrations at various times and temperatures. Also replenishment chart for salt baths. *A. F. Holden Co.*

56. Case Hardening Furnaces

Bulletin SC-159 describes equipment for gas, pack and liquid carburizing, including atmosphere generators and salt pot furnaces. *Surface Combustion*

57. Castings, Heat Resistant

Bulletin describes heat resistant castings for conveyors, roller hearths, trays, and radiation tube assemblies. *Standard Alloy Co.*

58. Cemented Carbide

16-page catalog of carbide blanks, inserts and tools, with five pages of technical data on applications. *Newcomer Products, Inc.*

59. Cleaner

Folder gives data on industrial metal cleaners for use with water in either still-tank or spray-washing equipment. *Solventol Chemical Products, Inc.*

60. Cleaner

Technical data sheet on AM aluminum cleaner to remove drawing, stamping, spinning compounds, rolling oils, marking inks and crayons as well as general shop dirt. *Cowles Chemical Co.*

61. Cleaning

Information on industrial washing machines which perform single or combined finishing operations. *Industrial Systems Co.*

62. Cleaning

Six-page Bulletin 121 discusses 28 difficult cleaning jobs where company's chemicals were successfully applied. *Kelite Products, Inc.*

63. Cleaning

Six-page bulletin includes concentrations for various metal cleaning applications and a handy list of cleaners for general industrial use. *E. F. Houghton*

64. Cleaning and Finishing

12-page illustrated catalog A-652 gives the complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines operating in large metalworking plants. *R. C. Mahon Co.*

65. Coatings

Information on Bonderite, nonmetallic coating which is resistant to corrosion and a good paint base. *Parker Rust Proof Co.*

66. Coatings and Packaging

43-page guide to better preservation and packaging deals with coatings, melting equipment and processing procedures for hot dip packaging. *Seal-Peel, Inc.*

67. Cold Finished Bars

12-page booklet describes how cold finished bars may eliminate heat treating, case carburizing, or grinding, minimize warpage, increase machining rates. Properties, applications and fabrication, including selective flame and induction hardening. *LaSalle Steel Co.*

68. Combustion Boats

Lecotherm boats are described in literature. *Laboratory Equipment Corp.*

69. Combustion Control

20-page booklet presents combustion charts for various fuels and describes portable instrument which measures content of oxygen and combustibles simultaneously and continuously. *Cities Service Oil Co.*

70. Combustion Equipment

Catalog 52 gives condensed pictorial review of oil and gas combustion equipment for production applications. 80 illustrations. *Hauck Mfg. Co.*

71. Compressors

12-page data book 107-C gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine Co.*

72. Controlled Atmospheres

Bulletin on Alnor Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on a.c. or enclosed battery. *Illinois Testing Labs.*

73. Coolant System

Bulletin on new atomizing system to aid cooling and lubricating of cutting tools. *Henry G. Thompson & Son Co.*

74. Copper Alloys

New issue of Lavingot Technical Journal contains discussion of the refining of secondary copper alloys. *R. Lavin & Sons, Inc.*

75. Copper Alloy Tubes

Extensively illustrated 32-page brochure deals with causes of corrosion and means of combatting them, as well as choice of materials for condenser tubes. *Revere Copper & Brass, Inc.*

76. Corrosion of Copper

24-page booklet B-36 discusses corrosive attack on copper and copper alloys. Includes tabulation of relative corrosion resistance of principal types of copper alloys. *American Brass Co.*

77. Corrosion Notebook

16-page "Corrosion Notebook" contains data on corrosion resistance of various types of stainless tubing and pipe. Also provides data by type of corrodent at various concentrations and general types of corrosion. *Carpenter Steel Co.*

78. Crucible Furnace

Four-page folder gives drawings and specifications of twin crucible furnace for melting nonferrous metals. Also comparison of production data for single versus twin crucible melting of red brass. *Morrison Industries, Inc.*

79. Cut-Off Machines

16-page bulletin gives facts and figures to aid in selection of the right cut-off machine for a given job. 14 models described. *Tabor Mfg. Co.*

80. Cutting Compounds

Data on cutting compounds for stainless steel and titanium. *Hangsterfer's Laboratories, Inc.*

81. Cutting Fluids

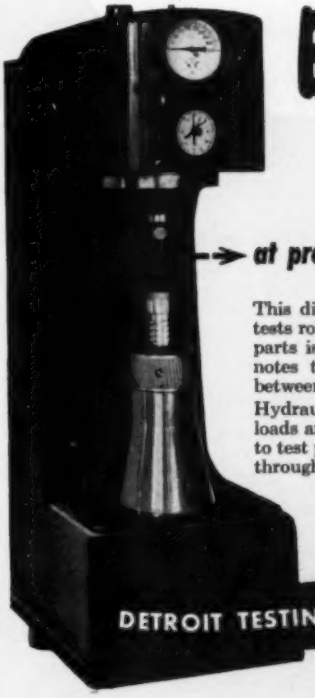
6-page article, "Water-Mix Cutting Fluids", describes selection, application and performance considerations. *D. A. Stuart Oil Co.*

82. Cutting Fluids

"More Than a Coolant Is Needed" is new booklet describing cutting fluids and lubricants. *D. A. Stuart Oil Co.*

83. Cutting Oil

New pamphlet, "Gulf Lasupar Cutting Oil", tells of new sulphurized oil



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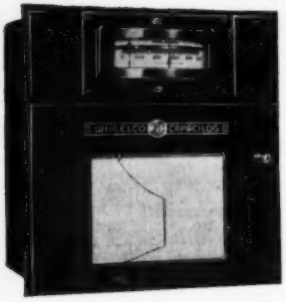

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which can be used effectively on stainless steel as well as other more easily machined alloys. *Gulf Oil Corp.*

84. Cutting Oil

80 pages of factual data on more than 50 typical metalworking jobs are presented in new edition of "Cutting and Grinding Facts". *Sun Oil Co.*

85. Descaling Process

8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. Treating cycle, chemistry of bath, raw materials and equipment design. *E. I. du Pont de Nemours*

86. Dew-Point Recorder

Detailed Bulletin 407 and Data Sheet AED 340-7 contain facts about dewpoint systems available for recording or record-controlling. Wide range of working temperatures. *Foxboro Co.*

87. Die-Casting Machines

Illustrated catalog shows complete line of die casting machines. *Kux Machine Co.*

88. Die-Casting Machines

Illustrated booklet giving specifications, application data and full explanations of two new production advantages on company's line of die-casting machines. *Lake Erie Engineering Corp.*

89. Die Castings

Bulletin on design and manufacture of aluminum die castings. *Die Casting Div., Hoover Co.*

90. Die Steel

Literature on Bethlehem cold heading die steel for high production in forging bolts, rivets, screws and other products at high speed. *Bethlehem Steel Co.*

91. Die Steel

Composition, properties and treatment of new water-hardening alloy steel for cold heading dies, which gives die life two to four times greater than steels formerly available. *Allegheny Ludlum Steel Corp.*

92. Die Steel

Bulletin shows comparison of wear resistance, toughness and size rigidity for five grades of high-carbon, high-chromium die steels. Also curves of impact and hardness versus tempering temperature. *Latrobe Steel Co.*

93. Dipping Baskets

Catalog B-7 illustrates and describes various kinds of dipping baskets and other processing carriers. *Rolock, Inc.*

94. Ductile Iron

Bulletin compares ductile iron with gray iron, malleable iron and cast steel. Eight examples of applications where ductile iron is profitably employed. *American Brake Shoe Co.*

95. Electric Contacts

12-page catalog describes properties and uses of line of electrical contacts. Included are silver, palladium, nickel and powdered metal compositions. *Gibson Electric Co.*

96. Electric Furnaces

Bulletin 473 describes rocking, automatic melting machine for various ferrous and nonferrous alloys. *Detroit Electric Furnace Div.*

97. Electropolisher

Bulletin on the theory and practice of electrolytic polishing of metallurgical samples includes description of Buehler-Waisman electropolisher. *Buehler, Ltd.*

98. Extrusions

Data on services in the field of aluminum extrusions. *Himmel Bros. Co.*

99. Fabrication Data File

Fingertip reference file contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

100. Ferro-Alloys

"Electromet Products and Service" gives helpful information about the use of ferrovnadium and other alloying metals. *Electro Metallurgical Co.*

101. Finishes

Four-page folder about Iridite gives the characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research Products*

102. Finishes for Aluminum

8-page reprint on surface preparation, application and use of electrochemical, organic, ceramic, mechanical and chemical finishes for aluminum and aluminum alloys. *Aluminum Co. of America*

103. Finishing Aluminum

4-page brochure describes three types of "Polychromatic" finishes for aluminum. *Reynolds Metals Co.*

104. Flaw Detection

Information on electronic equipment for nondestructive inspection of regular and irregular iron and steel parts. *Magnetic Analysis Corp. (Foerster)*

105. Flow Meters

12-page catalog 40 describes variable-area floor meters having precise tapered metal metering tubes and designed for both high temperature and high pressure. *Fischer & Porter Co.*

106. Forging Steel

Bulletin 31 on stainless forging problems includes specific data on alloy steels. *Timken Roller Bearing Co.*

107. Forgings

8-page Bulletin No. 5201 describes production facilities for engineering, planning, production, heat treating and machining of forgings, and for punching, welding, riveting, assembly and painting. *Pittsburgh Forgings Co.*

108. Forgings

Eight-page bulletin on heavy steel and alloy forgings. Applications. Company's facilities. *Titusville Forge Div.*

109. Forgings

20-page Catalog 51 describes various types of forgings, their strength and related data. Section on lifting devices. Numerous tables and drawings. *Merrill Bros.*

110. Forming

32-page brochure describes universal contour former which combines stretch, compression, and radial-draw forming. Over 100 photos show applications to extrusions, tubing, sheet, and rolled and formed shapes. *Cyril Bath Co.*

111. Forming

Bulletin on spinning, stamping and fabricating facilities. *C. A. Dahlin Co.*

112. Forming Magnesium

7-page article covers bending, spinning, stretch forming, deep drawing and other processes for magnesium sheet. From "Magazine of Magnesium". *Brooks & Perkins, Inc.*

113. Foundry Ceramics

Bulletin on ceramics that withstand heat shock. Applications to strainer and cut-off cores, gate tubes and precision cores. *American Lava Corp.*

114. Foundry Mechanization

36-page book 2439 gives case histories, foundry layout drawings, installation photographs of ferrous and nonferrous foundries. *Link-Belt Co.*

115. Furnace Controls

28-page catalog 51-1 on furnace and oven controls lists prices and illustrates variety of instruments such as temperature controllers, recorders, indicators and control valves. *Minneapolis-Honeywell Regulator Co.*

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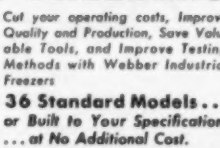

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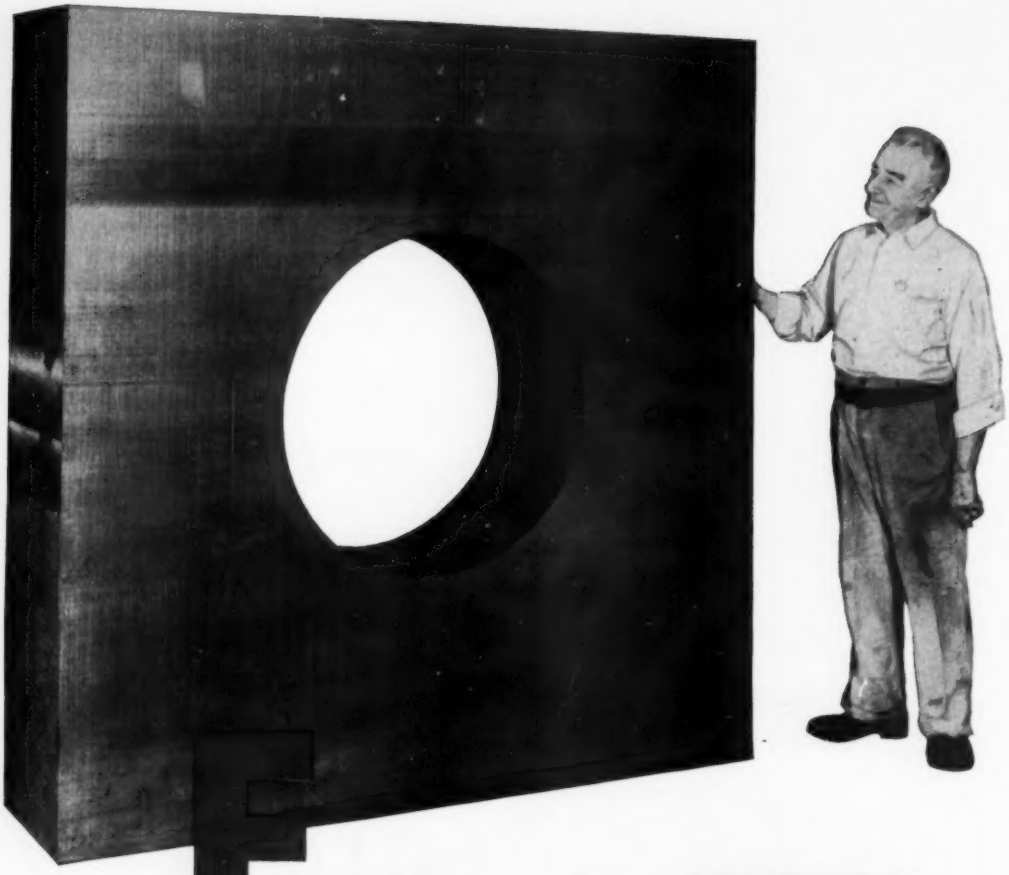

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116. Furnace Controls
Instruments and controls for heat treating furnaces are described in bulletin 51-750-51. *Hays Corp.*

117. Furnace Maintenance
"Maintenance Guide for Electric Heat Treating Furnaces" describes preventive maintenance program for electric furnace users. *Hevi Duty Electric Co.*

118. Furnaces
6-page illustrated folder describes FORGEatrol Furnace for heating tools for both forging and hardening. *Delaware Tool Steel Corp.*

119. Furnaces
12-page Catalog I-2 on method of atmospheric control for hardening high speed steel. *The Sentry Co.*

120. Furnaces
6-page folder describes 18 typical installations of gas-fired and electric furnaces of various types, complete with specially designed equipment for bright annealing, scale-free hardening, carbon restoration, carburizing and production heat treatment. *Electric Furnace Co.*

121. Furnaces
Complete catalog available describing high-speed gas furnaces designed primarily for heat treating high-carbon and alloy steels; also pot furnaces for salt, cyanide and lead hardening. *Charles A. Hones, Inc.*

122. Furnaces
44-page Catalog 112, well illustrated, features furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating. Also atmosphere generators and ammonia dissociators. *C. I. Hayes*

123. Furnaces
New all-purpose furnace described in bulletin HD-646 may be used for carburizing, nitriding, dry cyaniding, bright annealing and clean hardening. *Hevi Duty Electric Co.*

124. Furnaces
Bulletin on furnaces for annealing, normalizing, hardening, tempering, and forging. *Flinn & Dreffein Eng'g Co.*

125. Furnaces
Information on gas, oil and electric furnaces for heat treating. *Dempsey Industrial Furnace Corp.*

126. Furnaces
High temperature furnaces for temperatures up to 2000° F are described in leaflet. *Carl-Mayer Corp.*

127. Furnaces, Armor Plate
Illustrated 7-page booklet gives data on continuous hardening, pressure quenching, tempering line for steel plate. *The Drever Co.*

128. Furnaces, Atmosphere
Bulletin F-1 gives full description of versatile, controlled-atmosphere furnace for all steels from high carbon to high speed in range 1200 to 2800° F. *Delaware Tool Steel Corp.*

129. Furnaces, Direct-Fired
Bulletin SC-156 describes direct-fired furnaces for routine but essential jobs. Applications, descriptions, performance data. *Surface Combustion Corp.*

130. Furnaces, Laboratory
26-page booklet, "Construction of Laboratory Furnaces", contains many diagrams, charts and tables and information on how to construct furnaces. *Norton Co.*

131. Furnaces, Rotary Hearth
Folder giving drawings, dimensions, capacity, Btu required for drawing, annealing, forging. *Gas Machinery Co.*

132. Furnaces, Small Tool
4-page folder describes complete set-up for the heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace Co.*

133. Galvanizing Furnace
Four-page article describes installation of galvanizing furnace at Fairbanks-Morse. *Sunbeam Corp.*

134. Gas-Air Mixers
8-page bulletin 5-C gives engineering data on selecting and matching burners and mixers. Master table enables selection of mixer for any type of fuel gas. *Bryant Industrial Div.*

135. Gas Analyzer
Instrumentation data sheet 10.15-3a describes indicating and recording flue gas analyzer which gives continuous record of combustion analysis. *Minneapolis-Honeywell Regulator Co.*

136. Gas Burner Nozzles
Catalog 804-C gives capacities and other data on 19 sizes of straight and elbow-type nozzles. Spark and gas pilot ignition also explained. *Hauck Mfg. Co.*

137. Graphitic Tool Steels
48-page data booklet contains heat treating data, properties and 46 specific applications of four types of graphitic tool steel. *Timken Roller Bearing Co.*

138. Graphitization
12-page booklet gives 10-year research findings on graphitization phenomena encountered in steel castings. *Edward Valves, Inc.*

139. Hardfacing
New 40-page booklet, "Haynes Alloys — Hard-Facing Manual", tells what metals can be hardfaced, how to select right hardfacing material, lists step-by-step application procedures and industrial applications. *Haynes Stellite*

140. Hardness Tester
Bulletin F-1689-1 on Impressor hardness tester for aluminum, copper, brass, bronze, plastics. *Barber-Colman Co.*

141. Hardness Tester
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. *Wilson Mechanical Instrument Co.*

142. Hardness Tester
Circular on portable hardness tester in sizes for work 1 to 6 in. round and flat. *Ames Precision Machine Works*

143. Hardness Tester
Four-page bulletin on Brinell hardness tester weighing 26 lbs. for portable and stationary use. *Andrew King*

144. Hardness Tester
Bulletin ET 202 gives complete details on new Ernst portable hardness tester for direct at-the-job readings of all metal types and shapes. *Newage International, Inc.*

145. Heat Processing
New bulletin answers questions: what is to be heated, what sections are to be heated, why the material is to be heated, to what temperature and for what heating time. *Selas Corp. of America*

146. Heat-Resisting Alloy
Pyrasteel bulletin describes chromium-nickel-silicon alloy for service economy in resisting oxidation and corrosion at temperatures to 2000° F. *Chicago Steel Foundry Co.*

147. Heat-Resisting Paint
Bulletin 112351 describes metallic paint which withstands temperatures up to 1700° F. Data on composition, uses, method of application. *Speco, Inc.*

148. Heat Treating
Information on "Sure-Wear" process for heat treating high-speed cutting tools. *LR Heat Treating Co.*

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2. You get a Buyer's Guide...a complete catalog listing assembled thermocouples and replacement parts for all standard installations (special uses, too) . . . with full specifications, prices, illustrations so handily indexed ordering's a cinch.

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149. Heat Treating
Data Sheet lists complete line of heat treat services available at plant. *Vincent Steel Process Co.*

150. Heat Treating
Booklet describes complete diversified facilities for heat treating steel, aluminum and magnesium. *Pearson Industrial Steel Treating Co.*

151. Heat Treating
Catalog 116 contains 72 pages of heat treating data for carburizing, cyaniding, brazing, austempering and annealing processes. *Ajax Electric Co.*

152. Heat Treating
Ipsenlab periodic sheets show case histories on bright hardening, annealing and carburizing. *Ipsen Industries*

153. Heat Treating Baskets
Baskets designed for individual needs in handling parts. All types of trays, fixtures, retorts and carburizing boxes are described. *Stanwood Corp.*

154. Heat Treating Fixtures
Information on complete line of standard carburizing carriers that will handle odd-shaped parts of every type through carburizing and quenching to finishing. *Pressed Steel Co.*

155. Heat Treating Fixtures
Catalog B-8 contains descriptions and photographs of 75 custom-built fabricated alloy heat treating accessories. *Rolock, Inc.*

156. Heat Treating Furnaces
Performance charts on fuel-fired or electric furnaces for hardening, tempering, annealing, normalizing, stress relieving and aluminum treating. *Standard American Engineering Co.*

157. Heat Treating Guide
Chart guide constructed on slide rule principle for simplified hardening and drawing of tool steels. *The Carpenter Steel Co.*

158. Heating
Full details of high thermal release burner unit intended for use where quick heating and intense concentration of heat are desired. *Bloom Engineering*

159. Heating Equipment
16-page brochure contains reference information and table of steps in selecting industrial heating equipment. *Jensen Specialties, Inc.*

160. High-Temperature Alloys
"Haynes Alloys for High-Temperature Service" summarizes all available data on 10 super-alloys and lists physical and mechanical properties of two newly developed alloys. *Haynes Stellite Div.*

161. High-Temperature Alloys
"Thermalloy 30" gives property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

162. High Speed Steel
8-page bulletin on properties, heat treatment and uses of high speed steel containing 1.5% C, 12.5% W, 4.8% Cr, 5% V, 5% Co. *Vanadium-Alloys Steel*

163. Immersion Heating
Bulletin IE-11 gives complete details on how immersion pots save time and money in melting soft metals. High thermal efficiency for large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg.*

164. Immersion Pyrometry
Folder N 33-640 (1) presents both immersion thermocouple and immersion rayotube equipment for molten steel temperature measurement in 275-ton openhearth furnaces down to 1000-lb. high-frequency induction furnaces. *Leeds & Northrup Co.*

165. Induction Heating
Specifications for 10-kw high-frequency Model T-10-3. *Lepel High-Frequency Labs., Inc.*

166. Induction Heating
"Induction Heating . . . the machine tool that makes tall stories come true" presents case histories of how induction heating has increased production, reduced space and cut costs. *Westinghouse Electric Corp.*

167. Induction Heating
Illustrated bulletin on new 60-cycle induction furnace for heating aluminum, magnesium, copper and brass for forging, extrusion and rolling. *Loftus Engineering Corp.*

168. Induction Heating
Bulletin 1440 furnishes full details on the "Checklite" system for safety control through the use of oversized components built into every unit for longer service life and uninterrupted production. *Lindberg Engineering Co.*

169. Induction Heating
Bulletin "Induction Heating and Melting" contains well-known Selector Chart and table of heating and melting speeds for standard induction equipment. *Ajax Electrothermic Corp.*

170. Induction Melting
8-page illustrated article describes use of induction melting in improved technique for rotor-casting. *Ajax Engineering Corp.*

171. Industrial Photography
Book entitled "Functional Photography in Industry" describes processes and techniques applicable to a wide range of problems. *Eastman Kodak Co.*

172. Industrial X-Ray
New catalog, "Industrial X-Ray Accessories", provides complete listing of this equipment, including chemicals, dark-room accessories, filing equipment, processing tanks, dryers and radiation instruments. *Picker X-Ray*

173. Inspection
20-page bulletin on high-speed automatic gaging and sorting; 43 applications are illustrated. *Federal Products*

174. Instrument Centralization
Bulletin 85-20, consisting of 32 pages, describes conventional and graphic-type panelboards, as well as the measuring and control instruments utilized. *Minneapolis-Honeywell Regulator Co.*

175. Iron Powder
Information on sponge iron powder. *Ekstrand & Tholand, Inc.*

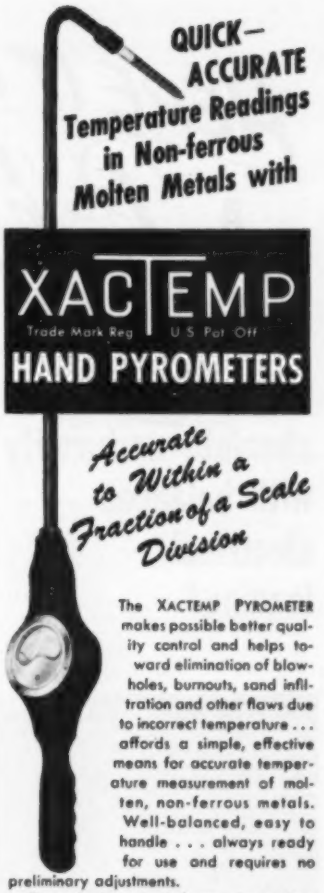
176. Leaded Steels
Folder on lead-bearing, cold finished bars which machine about 80% faster than B1113. *LaSalle Steel Co.*

177. Load Testing
Brochure 501 gives full details on universal testing machines in three ranges: Model TMU-A, 0-30,000, 0-6000, 0-600 lbs.; Model TMU-B, 0-15,000, 0-3000, 0-300 lbs. *National Forge & Ordnance Co.*

178. Lubricant
40-page booklet on Moly-sulfide lubricant records experience with 154 different applications. *Climax Molybdenum Co.*

179. Lubricant, Metalworking
Uses of colloidal graphite for hot metalworking operations (deep piercing, casting, forging, stretch-forming and wire drawing operations) are explained in bulletin No. 426-10F. *Acheson Colloids Co.*

180. Machining Alloy Steels
24-page bulletin (11 tables, 7 detailed drawings) helps determine satisfactory and economical combination of microstructure, tool form, cutting speed and rate of feed for each type of machining operation. *International Nickel Co., Inc.*



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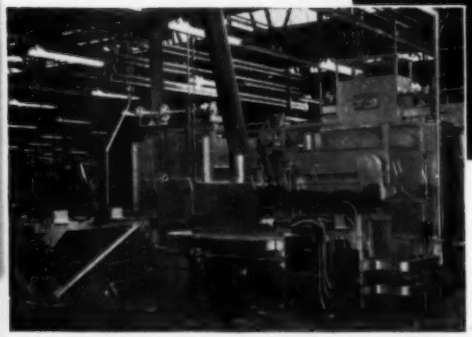

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181. Magnesium in B-36

Article in "Magnesium Topics" describes service experience with magnesium alloys in the B-36 bomber. *Dow Chemical Co.*

182. Magnesium Melting

Bulletin describes use of fabricated Amera-Mag steel crucibles in melting of magnesium alloys. *American Tank & Fabricating Co.*

183. Magnetic Alloys

20-page bulletin on the more important "magnetically soft" iron-nickel alloys containing from 20 to 90% nickel. *International Nickel Co.*

184. Malleable Iron

Metallurgy, treatment, and heat treated properties of malleable iron are described in Reprint 51-B. *Surface Combustion Corp.*

185. Mechanical Cleaning

76-page catalog No. 210 simplifies selection of power brush for the individual job; contains numerous illustrations of various types of brushes in operation. *Osborn Mfg. Co.*

186. Mechanical Cleaning

30-page booklet describes 12 case histories of how brushes were used for cleaning welds, stainless sheets, hot cast iron, automotive parts, brass fixtures, and mill products between processes. *Pittsburgh Plate Glass Co., Brush Div.*

187. Melting Furnaces

Eight-page Bulletin 560 describes stationary and tilting types of two-chamber melting furnaces. Applications to sand, permanent mold, centrifugal and die casting. *Lindberg Engineering*

188. Melting Pots

Bulletin 201-B on alloy cast iron melting pots for use in aluminum foundries, die-casting plants and smelting works. *American Car and Foundry*

189. Metal Analysis

Brochure describes operation of the Quantometer, which furnishes direct-reading, pen-and-ink records of quantitative spectrochemical analyses with extra copies, quickly and accurately. *Applied Research Labs.*

190. Metal Conveyor Belt

28-page Catalog No. 4 on metal belts for use in acid and alkaline baths, for heat treating furnaces and other applications. *Cyclone Fence Div.*

191. Metal Conveyor Belts

44-page illustrated catalog describes metal belts for quenching, tempering, annealing, hardening, brazing, carburizing, powder metallurgy and other applications. *Ashworth Bros., Inc.*

192. Metal Cutting

64-page catalog No. 28 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric Co.*

193. Metallograph

New research metallograph, described in catalog E-240, furnishes four different accurate images of same sample for complete identification with bright field, dark field or polarized light. *Bausch & Lomb Optical Co.*

194. Metallographic Polishing

Bulletin on equipment available for fine grinding of specimens with emery papers or wet-type silicon carbide papers or cloths. Includes hand and motor-powered grinders. *Buehler, Ltd.*

195. Micro Hardness Tester

Bulletin MHT gives complete details of microhardness tester. *Eberbach Corp.*

196. Microscopes

22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation for high-precision work. *Bausch & Lomb Optical Co.*

197. Microtome

Bulletin describes heavy-duty microtome for cutting hard objects, including metals, in steps of 20 microns. *Wm. J. Hacker & Co.*

198. Nonferrous Metals

"Metal of the Month" letters include market trends, statistics and other helpful data. *Belmont Smelting & Refining Works, Inc.*

199. Nonferrous Tubing

Folder on company's tubular products in copper, brass and aluminum, including special finned and corrugated tubing. *Fromson Orban Co., Inc.*

200. Oil Firing

Catalog 715 explains an easy means of standby oil firing for plants having seasonal shortages of natural gas. *Hauck Mfg. Co.*

201. Oil Quenching

Catalog V-1146 on self-contained oil cooling equipment. Detailed solutions to typical problems. Selection tables for volume of oil required and oil recirculation rates. *Bell & Gossett Co.*

202. Optical Pyrometer

Catalog 80 describes pyrometer for quick, accurate temperature readings on minute spots, fast-moving objects and small streams in a temperature range from 1400 to 7500° F. *Pyrometer Instrument Co.*

203. Oxygen Cutting

15-page article, "Oxygen Cutting of Defense Equipment Materials", covers various types of steel. *Air Reduction Sales Co.*

204. Phosphate Coating

12-page bulletin, "Phosphate Coating Chemicals and Processes", gives technical data on following uses: paint bonding, rust proofing, protecting friction surfaces, improving drawing and extrusion. *American Chemical Paint Co.*

205. Phosphor Copper

20-page book on how to use phosphor copper as a deoxidizer and hardener for bronze and brass alloys in foundries and rolling mills and for the making of phosphor bronzes, brazing metal and other alloys. *Ajax Metal Div.*

206. Photography

Catalog, "Kodak Sensitized Materials for the Scientific and Industrial Laboratory", tells of special films, plates and pellicles, transmission curves of filters and filter combinations commonly used in photography. *Eastman Kodak Co.*

207. Photo Reproduction

Selection chart lists 11 types of originals and, for each, the photographic material and process for successful reproduction. *Eastman Kodak Co.*

208. Pickling Compound

Folder on "Rodine" tells of its use in pickling solutions to prevent embrittlement of steel. *American Chemical Paint*

209. Pickling Solutions

D-scale-RS, substitute for liquid pickling, is described in Bulletin 36. May be used in barrel work as well as tanks. *Magnus Chemical Co.*

210. Plating Barrels

Folder illustrates and describes equipment for barrel plating with unique contact arrangement for maximum current distribution. *Daniels Plating Barrel & Supply Co.*

211. Plating Generators

Catalog MP-700 describes motor-generator set for electroplating, anodizing, electrocleaning, or electropolishing in either large or small-scale operations. *Columbia Electric Co.*

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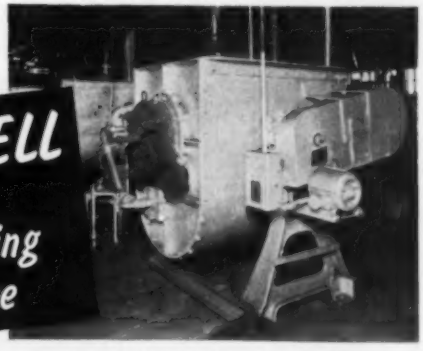

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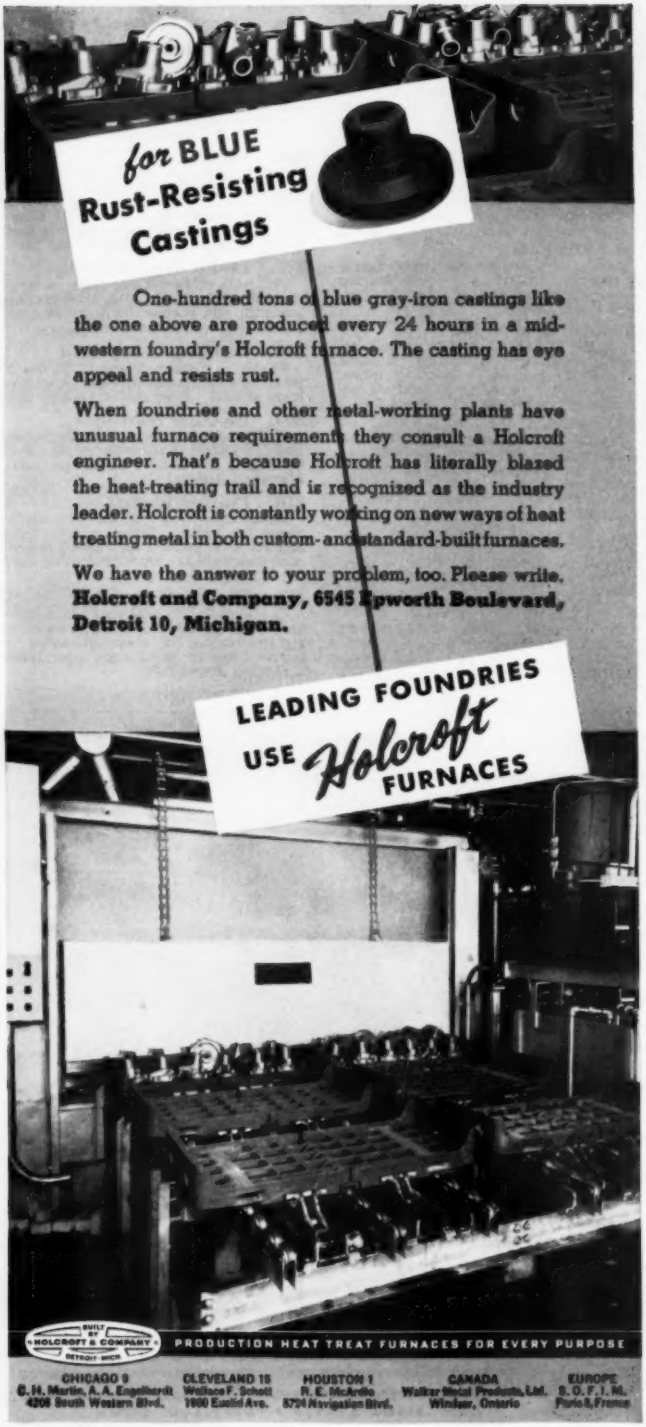
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212. Polishing and Buffing
6-page bulletin on application of single-spindle machine in polishing formed parts having either plane or curved surfaces. *Vanott Machine Corp.*

213. Polishing Materials
20-page booklet describes and includes samples of emery, aluminum oxide and silicon carbide papers, and 12 polishing cloths. Trade names, particle sizes. *Buehler, Ltd.*

214. Powder Metal Parts
Bulletin shows 20 powder metal parts with statement of material, method used previously and cost reduction by powder metallurgy. *Wel-Met Co.*

215. Precision Casting
Illustrated folder shows samples of investment castings produced of various ferrous and nonferrous alloys. Advantages of these castings. *Engineered Precision Casting Co.*

216. Precision Casting
12-page, illustrated booklet on precision casting with emphasis on the most widely used equipment and supplies. Check list of applications in various fields included. *Alexander Saunders*

217. Precision Castings
12-page booklet, "High-Quality Precision Castings for Industry", describes company's plaster mold casting process. *Atlantic Casting & Engineering Corp.*

218. Preheating for Welding
10-page article reviews information and experience to produce crack-free welded joints under a wide variety of conditions. Recommended preheating temperatures for 71 commercial steels. *Tempil Corp.*

219. Presses, Bending
Steelweld presses for bending, forming, blanking, drawing and multi-punching operations are described in catalog No. 2010. *Cleveland Crane & Engineering Co.*

220. Protective Finish
Comprehensive study of application of black oxide finish is given in latest catalog, "Protective Finishes and Heat Treating Salts for Metals—Black Magic". *Mitchell-Bradford Chemical Co.*

221. Pyrometer Equipment
A new Buyers' Guide for pyrometer supplies, No. 100-4, is ready for distribution. *Minneapolis-Honeywell Regulator Co.*

222. Pyrometers
Complete information on Xactemp pyrometers: Type LT-840 and all accessories are illustrated and described; also Xactline straight-line temperature control for use with any standard pyrometer controller. *Claud S. Gordon Co.*

223. Pyrometers
Bulletin GEC-713 and Bulletin GEC-714 describe line of pyrometers and thermocouples. *General Electric Co.*

224. Quench Conveyor
8-page bulletin on continuous quench tank conveyor and other production equipment. *The Klaas Machine & Mfg.*

225. Quenching
Bulletin 820 gives detailed description with complete specifications on various size automatic quenching tanks for use with continuous heat treating equipment. *American Gas Furnace Co.*

226. Quenching Oil
8-page booklet on applications and cost reductions in oil-quenching installations. *Sun Oil Co.*

227. Radiography
34-page book, "Industrial Applications of the X-Ray", features radiography of castings and weldments. *General Electric X-Ray Corp.*

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228. Refractories
8-page bulletin 316 discusses uses of Sillimanite super-refractories; 7 types of application dealt with. *Chas. Taylor Sons Co.*

229. Refractories
New 12-page brochure presents products for casting special refractory shapes and for gunning and slap troweling applications, for services through 3000° F. *Johns-Manville*

230. Refractories
20-page booklet gives technical information of a basic nature on super refractories. Contains text, charts, tables, illustrations and application data. *Refractories Div., Carborundum Co.*

231. Regrinding of Rolls
Article discusses influence of various factors on the total cost of regrinding hot mill rolls, from "Grits and Grinds". *Norton Co.*

232. Rhodium Plating
Directions for rhodium plating, with reference to use as replacement for usual plating metals. *Baker & Co., Inc.*

233. Roll Temperatures
Bulletin 405 describes new measuring head for recording and controlling roll surface temperatures. *Foxboro Co.*

234. Rotary Straightener
Catalog describes two-roll rotary straightener for round tubes and bars 1/16 to 3/16 in. O.D. *Medart Co.*

235. Rust Preventive
Technical information on zinc phosphate type of rust preventive conforming to Service specifications. *American Chemical Paint Co.*

236. Rust Preventive
"How" book shows how slushing and degreasing problems can be eliminated by Vapor-Wrapper method of packaging machines and parts. *Nox-Rust Chemical Corp.*

237. Rust Preventive Use Chart
New rust preventive use chart No. 1151 lists the latest U. S. Government spec for preservative oils and coatings for packaging. *Nox-Rust Chemical*

238. Safety Valves
Bulletin 400 describes safety valves for instantaneously shutting off fuel in case of power failure to some essential unit. *Western Products, Inc.*

239. Salt Bath Descaling
12-page bulletin B-40 describes continuous and batch descaling lines for removing oxide from iron, steel, bronze, copper, stainless steel and titanium. *Drever Co.*

240. Salt Baths
32-page bulletin, "Liquid Salt Baths", discusses heat treating salts for tempering, annealing, neutral hardening, martempering and carburizing. Heat treating data. *E. F. Houghton & Co.*

241. Saw Blades
Bulletin on power hacksaw blades of M-2 type high speed steel. *Henry G. Thompson & Son Co.*

242. Seamless Tubing
Bulletin TB-340 is a guide to the use of seamless mechanical tubing, hot finished, cold drawn or roto-rocked. *Babcock & Wilcox Co.*

243. Shotblasting
"A Primer on the Use of Shot and Grit" is the title of an attractive 16-page booklet on problems of blast cleaning operations. *Hickman, Williams & Co.*

244. Shot Peening
Catalog describes selection and use of shot and grit for cleaning and peening. *Cleveland Metal Abrasive Co.*

245. Silicone-Base Finish
New brochure on silicone-base heat-resistant finish is now ready. *Midland Industrial Finishes Co.*

246. Soldering Aluminum
Article on latest techniques and materials developed for soldering aluminum, from "Reynolds Technical Advisor". *Reynolds Metals Co.*

247. Spark Testing
20-page spark test guide features spark diagrams of 13 standard tool and die steels. *Carpenter Steel Co.*

248. Spinning Zinc
Folder gives examples of articles spun from zinc. *American Zinc Institute*

249. Spray Booths
Bulletin has 15 pages of photos, diagrams and information on hydro-whirl spray booths in all sizes and arrangements for manual or automatic spraying. *Peters-Dalton, Inc.*

250. Spring Wire
Detailed information on Pittsburgh oil tempered spring wire to help solve coiling, knotting, forming and twisting problems. *Pittsburgh Steel Co.*

251. Stabilized Stainless
26-page reprint, "Conservation of Columbium", a summary of British and American experience with stabilized stainless steels. 56 contributors discuss relative acceptability of titanium vs. columbium for stabilized stainless steel. Aircraft, chemical, petroleum applications; welding, forming, tubing, castings, sheet, plate, bars, electrodes. *Metal Progress*

252. Stainless Fasteners
20-page catalog provides product specifications to aid in ing and ordering stainless steel ings. *Star Stainless Screw Co.*

253. Stainless Steel
8-page guide to Enduro stainle composition, physical, electric mechanical properties of 300 series. Corrosion data for 600 m *Republic Steel Corp.*

254. Stainless Steel
32-page booklet on corrosion ance of austenitic stainless ste tables show results of tests neutral and alkaline solutions. *national Nickel Co.*

255. Stainless Steel
Properties and composition cipitation hardenable stainless (16 Cr, 4 Ni, 4 Cu). *Coope Foundry Co.*

256. Stainless Steel
Weekly lists with analyses plates in stock. *G. O. Carlson,*

257. Stainless Steel Powd
6-page Bulletin No. 1 descri of a new Type 316 stainless which overcomes previous lim of austenitic stainless steel for metallurgy. *Vanadium-Alloys S*

258. Stainless Tubing
Bulletin 143 on Type 410 stainless tubing. Forging, ma welding, heat treatment, pr *Babcock & Wilcox Co.*

259. Stampings
16-page steel stamp catalog letter, figure, and inspection marking dies, embossing di molders and numbering ms *Dickey-Grabler Co.*

260. Steel, Low-Alloy
Booklet on Hi-Steel, which ha twice the working strength of steels plus the ability to withst pact. *Inland Steel Co.*

261. Steel, Low-Alloy
Well-illustrated 8-page fo N-A-X low-alloy steels lists properties and test specification *Lakes Steel Corp.*

262. Steel Tubing
24-page bulletin 17 deals w chanical applications of steel Many of the uses are illustrat *tional Tube Div.*

263. Stereomicroscopes
20-page brochure on microsc three-dimensional magnificatio 45 diameters. *Bausch & Lomb*

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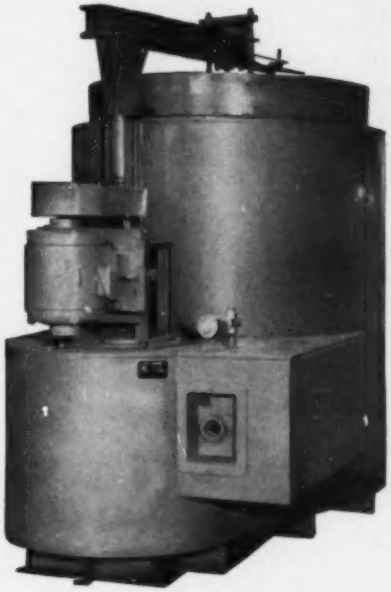

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264. Straightening Wire

Bulletin 52-AA describes straightening machine for wire in size range from 1/16 to 1 in. diameter, at speeds up to 200 ft. per min. *Medart Co.*

265. Surface Grinding

See review on p. 21

266. Surface Hardening of Stainless Steels

24-page "Story of Malcomizing" describes surface hardening of stainless steels. Includes case histories. *Lindberg Steel Treating Co.*

267. Temperature Control

8-page bulletin describes new temperature-control unit that automatically monitors up to 20 individual temperature points a minute, with excess-temperature alarm or cut-out. *Illinois Testing Labs.*

268. Temperature Control

36-page Bulletin P1245 on new electronic instruments for recording and indicating a wide variety of variables. Includes charts, wiring diagrams, many photographs. *The Bristol Co.*

269. Temperature Control

Article describes control installation for gas-fired annealing furnace at Falk Corp. *Wheelco Instruments Div.*

270. Temperature Control

Catalog of improved pyrometer supplies gives data on thermocouples, protection tubes, extension wire, insulations and terminal heads. *Arklay S. Richards Co., Inc.*

271. Testing

Bulletin on mechanical and nondestructive testing and on certification in accordance with procedure set up by the American Standards Association. *American Standards Testing Bureau*

272. Testing Equipment

New 80-page illustrated catalog lists testing and measuring equipment for laboratory and production line use. Photos, diagrams, descriptions of over 130 pieces of testing and measuring equipment. *General Electric Co.*

273. Testing Machine

Bulletin 40 contains full details on the new low-cost Super "L" testing machine with Select-o-Range indicating system. *Tinius Olsen Testing Machine Co.*

274. Thermocouples and Pyrometer Accessories

56-page book comprising a User's Manual, illustrated Buyers' Guide with specifications and prices and thermocouple calibration data. *The Bristol Co.*

275. Thermocouple Wells

Catalog 200-2 furnishes up-to-date data on thermocouple wells. *Minneapolis-Honeywell Regulator Co.*

276. Thickness Tester

Bulletin on measurement of wall thickness from one side by sonic method. *Branson Instruments, Inc.*

277. Tool & Die Steel Manual

Revised edition of "Matched Tool and Die Steel Manual" deals with selection, heat treating and uses of tool steels. *Carpenter Steel Co.*

278. Tool Furnace

Bulletin DF-2 describes furnace for cold-shank heating of chisels for both forging and hardening. *Delaware Tool Steel Corp.*

279. Tool Steel Selector

Twist the dial of the 9-in. circular selector and you can read off the tool steel for your application. *Crucible Steel Co. of America*

280. Tool Steels

Booklet describes seven tool steels for machining and die work, with emphasis on applications in fastener industry. *Universal-Cyclops Steel Corp.*

281. Tool Steels

Stock list of available tool and die steels. *Reliable Steel Co.*

282. Tubing

Technical discussion of fabrication and forging of steel tubing is given in Handbook F-3. *Ohio Seamless Tube Co.*

283. Tubing Machine

"Machine Hot-Forms Tubing into Complex Parts" treats the economic advantages of hot forming in the same plant where the precision-sized tubing is produced. *Tube Reducing Corp.*

284. Vacuum Pump

Bulletin describes air pressure or vacuum pumps for laboratory applications. Performance and size specifications. *Eberbach Corp.*

285. Vacuum Pumps

Illustrated data sheet describes and charts characteristics of new diffusion pumps and provides data on fore-vacuum, fractionation, speed, baffles and installation. *Distillation Products*

286. Vacuum Supplies

40-page illustrated catalog 11K listing research high-vacuum equipment, pumps, oils, gages and supplies. *Research Vacuum Supply Co.*

287. Vanadium Recovery

Six-page article, "Recovery of Vanadium and Other Alloys in the Acid Electric Furnace", from Vancoram Review. Extensive tabular data. *Vanadium Corp. of America*

288. Vapor Degreaser

Vapor degreaser described and diagrammed in folder. Data on different models.. *Topper Equipment Co.*

289. Vapor Degreasing

Pamphlet on properties and use of trichlorethylene as a solvent for vapor degreasing. *Niagara Alkali Co.*

290. Welded Steel Pipe

36-page brochure, "Continuous-Weld Pipe", describes manufacture and gives tabular data on various types of the product. *Wheeling Steel Corp.*

291. Welding

Catalog No. 17 describes the Aircomatic welding process, based on bare filler wire with inert shielding gases. *Air Reduction Sales Co., Inc.*

292. Welding Armor Plate

Booklet discusses new low-hydrogen, ferritic electrodes for welding armored ships and tanks. *Arcos Corp.*

293. Welding Electrodes

Wall chart of bronze welding electrodes gives AWS-ASTM designations, applications, properties and other data. *Ampco Metal, Inc.*

294. Welding Flux

16-page booklet describes use of back-up flux on the underside of welded seam. Application chart for 25 steels and nonferrous metals. *Solar Aircraft*

295. Wire-Coiling Machine

Bulletin C-52 describes machine to coil resistance-wire uniformly, rapidly and accurately. *Driver-Harris Co.*

296. Wire, Nonferrous

Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel silver, brass and aluminum wire. *Little Falls Alloys*

297. Wire Straightening

Bulletin 52-C describes precision machine for straightening small wire with extreme accuracy. Applies to round wire 0.007 to 0.125 in. diameter of ferrous or nonferrous metal. *Medart Co.*

298. X-Ray Inspection

Bulletin 400-520 on jib-crane unit for applications where horizontal and vertical travels of standard tubestand are inadequate. *Westinghouse Electric*

299. Zinc Analysis

Article on quantitative spectrographic analysis of zinc die-casting alloys, from Spectrographer's News Letter. *Applied Research Laboratories.*

300. Zinc Galvanic Anode

40-page booklet, "Zinc as a Galvanic Anode", deals with cathodic protection against corrosion. Numerous tables and charts. *Federated Metals Div.*

July, 1952

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19	44	69	94	119	144	169	194	219	244	269	294
20	45	70	95	120	145	170	195	220	245	270	295
21	46	71	96	121	146	171	196	221	246	271	296
22	47	72	97	122	147	172	197	222	247	272	297
23	48	73	98	123	148	173	198	223	248	273	298
24	49	74	99	124	149	174	199	224	249	274	299
25	50	75	100	125	150	175	200	225	250	275	300

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name _____

Title _____

Company _____

Address _____

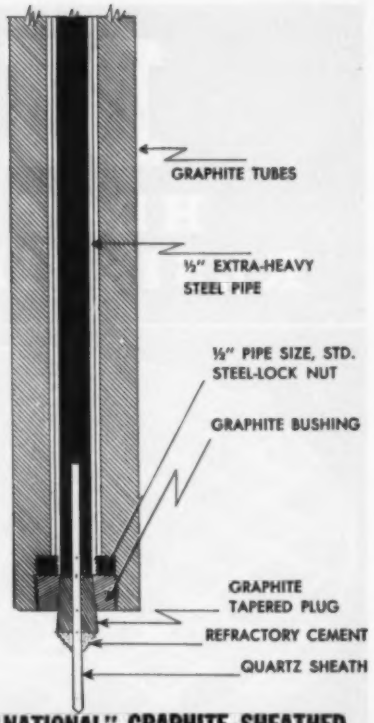
City and State _____

Postcard must be mailed prior to Oct. 1, 1952.
Students should write direct to manufacturers.

In Furnace and Foundry...

These SMALL PARTS do a BIG JOB

● High temperature applications of "National" Carbon and Graphite are not limited to big-tonnage items. A part of National Carbon's service is to develop *any* application, however small, where the unique properties of carbon and graphite assure a convenience and economy to the user. In the following two instances, a few *pounds* of graphite serve literally *tons* of metal . . . efficiently and at a saving.



"NATIONAL" GRAPHITE-SHEATHED THERMOCOUPLE ASSEMBLY (Typical)

Only graphite could provide the degree of low-cost, trouble-free protection required by thermocouple assemblies of this type for the immersion method of measuring open hearth and electric furnace bath temperatures. Reclamation and maintenance for re-use are simple, quick, and economical. Molten metal won't stick to the graphite parts and they're immune to thermal shock.

"NATIONAL" [illegible] TUBES

Can't be equalled by any other ma[illegible]duction of purifying gases into molten metal. Graph[illegible] melt in the bath, can't contaminate the metal. Its low coefficient of expansion prevents cracking and spalling. Metal and dross do not adhere tightly to it. And whatever gases are used, graphite will not corrode.

HERE'S HOW TO LICK HY MEET

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PLEASE SEND INFORMATION ON:

☐ Thermocouple Sheath Parts ☐ Fluxing Tubes

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A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, New York
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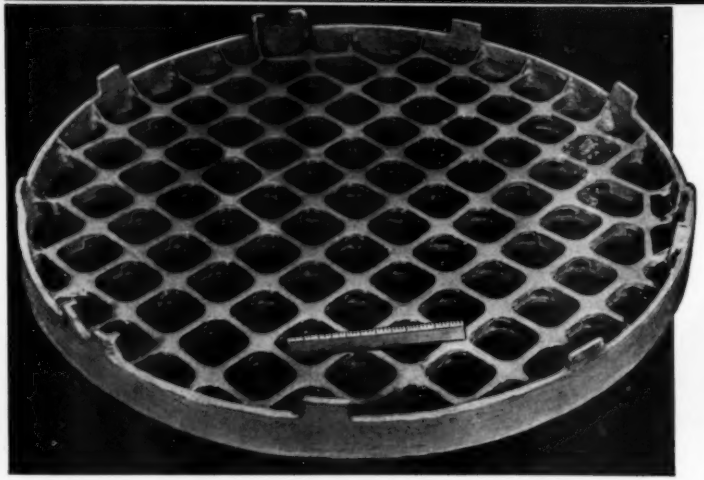
. . . mark phenomenal acceptance of "EVEREADY" No. 1050 Industrial Flashlight Batteries by a broad cross-section of industry. Delivering twice the usable light of any battery we've ever made before, it will not swell, stick or jam in the flashlight . . . has no metal can to leak or corrode.

BLAST FURNACE LININGS • BRICK • CINDER NOTCH LINERS • CINDER NOTCH PLUGS • SKIMMER BLOCKS • SPLASH PLATES • RUNOUT TROUGH LINERS • MOLD PLUGS • TANK HEATERS

MISCO
HEAT RESISTING ALLOYS

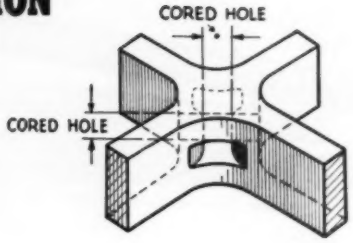


BOTTOM
GRID
FOR
ANNEALING
BASKET

MISCO B
25% Cr — 12% Ni
55″ O.D. WT. 450#

THE MOST EFFICIENT CONSTRUCTION FOR ANY KIND OF GRID TRAY

Grid intersections are cored horizontally and diagonally through the neutral axis. Metal thus removed from regions of low stress is added to areas of high stress, where it increases load capacity, reduces distortion, and gives much longer life. U. S. PATENT 2242554.



SPECIFY MISCO Heat Resisting Alloys—*CAST and ROLLED*—For all Heat Treating Equipment

Furnace Parts • Roller Rails • Roller Hearths • Conveyor Rolls • Trays • Retorts • Chain • Muffles • Walking Beam Conveyors • Carburizing and Annealing Boxes Dipping Baskets • Cyanide and Lead Pots • Thermocouple Protection Tubes • Pickling Equipment • Centrifugal Castings • Miscellaneous Castings and Rolled Bars • Sheets, Plates, Tubes, Nuts and Welding Rod for use at high temperature or under corrosive conditions.

ALLOY CASTING DIVISION
Michigan Steel Casting Company

MISCO
Heat and Corrosion Resistant Alloys

One of the World's Pioneer Producers and Distributors of Heat and Corrosion Resisting Alloys

1999 GUOIN STREET • DETROIT 7, MICHIGAN

"The Peacock's Complaint"

has a moral for Cutting Fluid users

Aesop's Story:

Among the fables of Aesop, is the story of the Peacock that lamented to the Goddess of the Birds its inability to sing like the Nightingale. Finally, losing patience, the Goddess rebuked the magnificent bird, saying, "Peacock, none of us can have *all* the fine qualities. The Nightingale is musical, the Eagle is powerful, the Owl is wise, while you are most beautiful of all the birds. Be content, for had you the voice of the Nightingale, you could not have your own beauty."

The Moral:

Just as the Peacock in Aesop's fable excelled in beauty of plumage but not of voice, so does no single cutting fluid excel in every desired characteristic.

For example, in machining tough, stringy materials, a cutting fluid must have high anti-weld characteristics to prevent scuffing and resultant poor surface finish. However, on free machining materials the anti-weld requirement must be balanced for maximum tool life consistent with desired finish.

The fable simply points up the fact that there is no *universal* cutting fluid to give best results on every job.

The Stuart Oil Co. and its representatives offer you no compromise products. They are prepared to help you correctly select and apply the cutting fluids that will give you the best possible results on *your* particular work.

More Than a "Coolant" is Needed

D.A. Stuart Oil co.

EST. 1865 LIMITED

TIME-TESTED CUTTING FLUIDS AND LUBRICANTS

2743 S. Troy St., Chicago 23, Ill.

SEND FOR BOOKLET entitled *More Than a "Coolant" is Needed*

CLIP TO YOUR COMPANY LETTERHEAD AND MAIL

to D. A. Stuart Oil Co., Ltd., 2743 S. Troy St., Chicago 23, Ill.

Your Name .....

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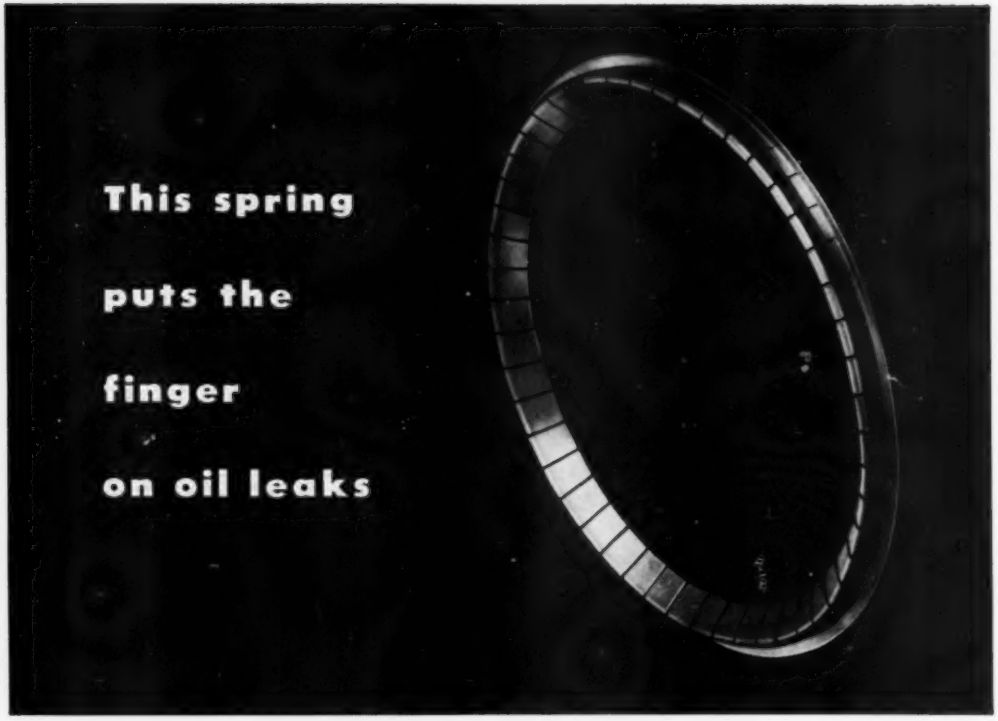

IT'S MADE OF BERYLCO BERYLLIUM COPPER

An ideal bearing oil seal does more than retain the lubricant. It seals against—and is resistant to—mud, dirt, oil, grease and other foreign matter. It resists the corrosive action of water. Such is this seal, made by The Garlock Packing Company.

The beryllium copper spring, formed from Berylco 25 strip, is a vital part of the Garlock oil seal. Each finger independently transmits uniform pressure against the synthetic rubber sealing member. This action provides a low-friction bearing seal on high- or low-speed shafts, even when considerable lateral shaft movement is encountered.

Berylco was chosen for this application because of its ideal spring properties—its resistance to corrosion, fatigue and moderate temperature changes, its formability. Berylco 25 can be formed without regard to grain direction, and subsequent heat-treating produces maximum spring properties.

Take advantage of the technical knowledge of the world's largest producer of beryllium copper. Blueprint your problem or send for sample material.

VALUABLE ENGINEERING INFORMATION on Berylco beryllium copper is compiled in a series of monthly technical bulletins. To receive your copy regularly, write on your business letterhead.

Tomorrow's products are planned today —with Berylco beryllium copper

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New York · Springfield, Mass. · Cleveland · Dayton · Detroit · Chicago · Minneapolis · St. Louis · Seattle · San Francisco · Los Angeles

Representatives in principal world-trade centers

Don't buy heat treating equipment blindfolded! Results obtained on sample batches of your products in this spic and span Ajax Metallurgical Service Laboratory can be duplicated in your own plant.

Say Goodbye to Guesswork

ON HEAT TREATING RESULTS AND COSTS!

Without charge or obligation, the Ajax Metallurgical Service Laboratory will treat specimen parts by any of the following processes:

CARBURIZING
CYANIDE HARDENING
NEUTRAL HARDENING
ANNEALING OR HARDENING STAINLESS STEEL
BRAZING
HARDENING HIGH SPEED STEEL
AUSTEMPERING
MARTEMPERING
PROCESS ANNEALING
CYCLIC ANNEALING
SOLUTION HEAT TREATMENT
DRAWING (Tempering)
DESCALING, CLEANING
DESANDING

What about the quality of the finished work? Will it be scale-free, devoid of decarb? Will the heat treatment prevent distortion and thereby reduce or eliminate costly grinding or finish machining operations? How much production will the furnace give per hour, and what floor space will be needed? What will the power, labor, maintenance and other heat treating costs amount to? *In short, will your proposed new furnace live up to the manufacturer's enthusiastic claims for it?*

You can be absolutely sure on all of these points *before* you buy an Ajax Electric Salt Bath Furnace for these reasons:

1—No Ajax salt bath furnace is ever sold until Ajax engineers—backed with experience in over 4,000 installations—are convinced it will do the job to your entire satisfaction as well as to theirs.

2—Before buying, we strongly urge that you utilize the facilities of the full commercial scale Ajax Metallurgical Service Laboratory. Send or bring batch lots of your materials for heat treating under actual working conditions. Let us prove beyond any question of doubt what can be done, how it can be done, and under exactly what conditions.

3—Once your furnace is installed, an Ajax engineer will visit your plant to double check, to instruct, and to make sure that on-the-job operation fully matches your expectations.

This policy has resulted in the most outstanding patronage ever accorded any heat treating furnace, both in the importance and number of users. A list of users is available on request. The high percentage of customers who have re-ordered Ajax heat treating equipment is unparalleled in the furnace industry.

AJAX ELECTRIC COMPANY, Inc.

World's Largest Manufacturer of Electric Heat Treating Furnaces Exclusively

910 Frankford Ave.
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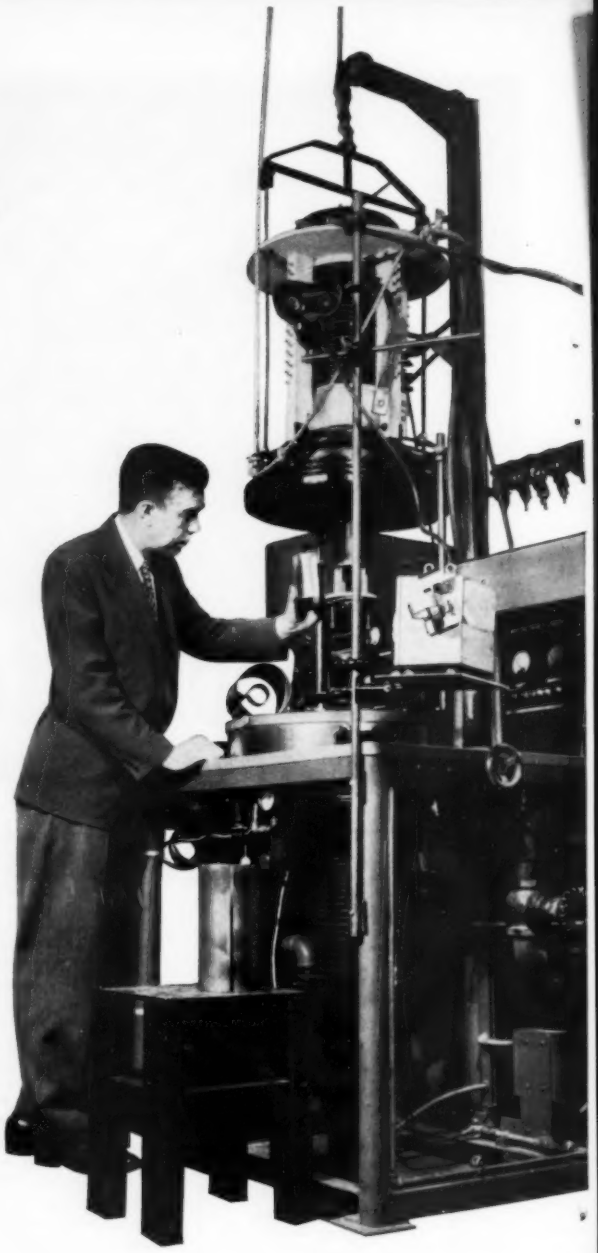
AJAX ELECTRIC SALT BATH FURNACES

Fast heating and less O_2 with a DPi **high vacuum** furnace



This DPi high vacuum furnace is being used by the Mineral Products Division of the National Bureau of Standards to study phase equilibria of binary and ternary metal-ceramic mixtures.

Operating at pressures of 10^{-4} to 10^{-5} mm Hg, the furnace heats up to 1800 C in ten minutes and is held for one half hour. The absence of thermal conductivity in vacuums of this order helps make such rapid heating possible and temperatures easier to hold.

Moreover, it's usually easier and cheaper to get rid of oxygen by high vacuum rather than to try diluting. With a vacuum of 1×10^{-5} mm Hg, the oxygen content is reduced to 3 parts per billion—a content achieved only with considerable difficulty utilizing an inert atmosphere.

DPi's wealth of experience in high vacuum research and engineering, combined with expert manufacturing experience in metal-heating problems, makes it possible for us to develop trouble-free high vacuum metallurgical furnaces to meet your needs precisely. We can make provisions for addition cups, interchangeable furnace assemblies, sight windows, or whatever you need, and still hold the vacuum.

Whether you are interested in high vacuum metallurgy, a single pump, or any high vacuum application, we will be glad to discuss your problems with you. Just write or phone ***Distillation Products Industries,*** Vacuum Equipment Department, 753 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

DPi

high vacuum research and engineering

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3500 Eastman Organic Chemicals for science and industry

for economy in coiling,
knotting, forming —

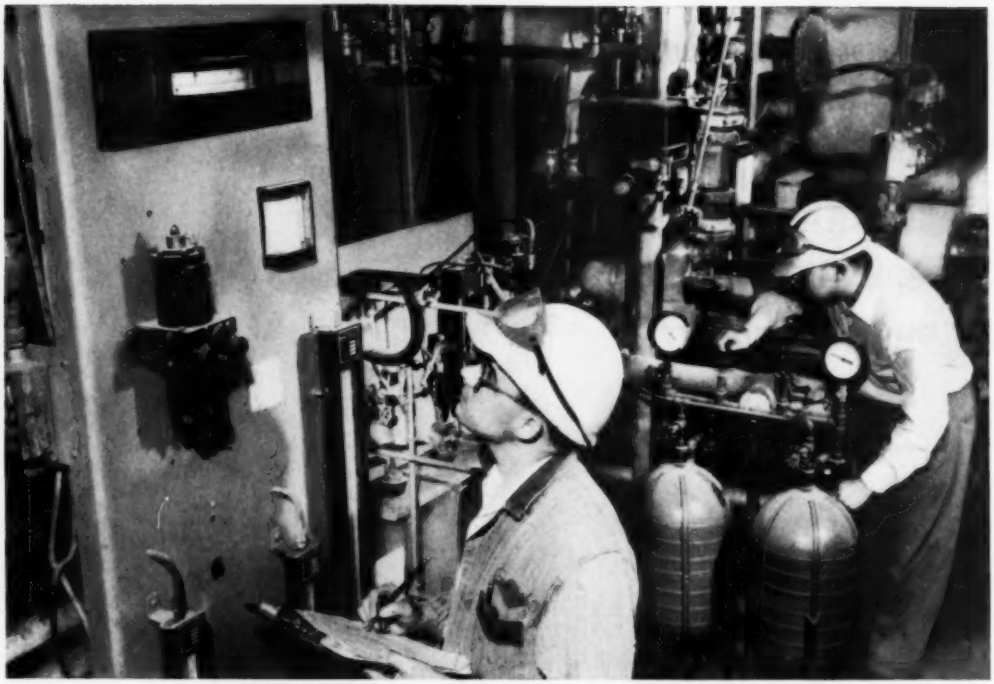
use **Pittsburgh**

M. B. Hard Drawn
and Oil Tempered
SPRING WIRE

You, like many others will find that Pittsburgh Spring Wire gives you economy in your operations that looks good on your cost sheets. The close control of chemistry, the precision wire drawing at Pittsburgh Steel gives you a wire that is best suited for your coiling, knotting, and forming operations. It has uniformly high tensile strength and the stiffness to give you the best finished spring. Its size accuracy and ductility make it easy to work in your machines. Available in M. B. and H. B. grades. Specify Pittsburgh Steel Spring Wire for all your production. For information write Department MP, Grant Building, Pittsburgh 30, Pa.

Pittsburgh Wire

A product of **PITTSBURGH STEEL COMPANY**



CHEMICAL PLANT HCL FUMES HAVE HAD NO EFFECT ON THIS PYROMETER'S ACCURACY; ABOVE, OPERATOR TAKES PYROMETER READING

"Extremely Corrosive Atmosphere— No Change in G-E Pyrometer Accuracy"

The calibrated accuracy of General Electric pyrometers is within ¾ of 1 per cent of full scale. And these instruments are built to take excessive punishment. A large eastern chemical manufacturer writes: "We use the HP-3 pyrometer to control the temperature of heat transfer oil. The surrounding atmosphere is extremely corrosive, due to hydrochloric acid fumes—yet there has been no sign of operational difficulty or failure."

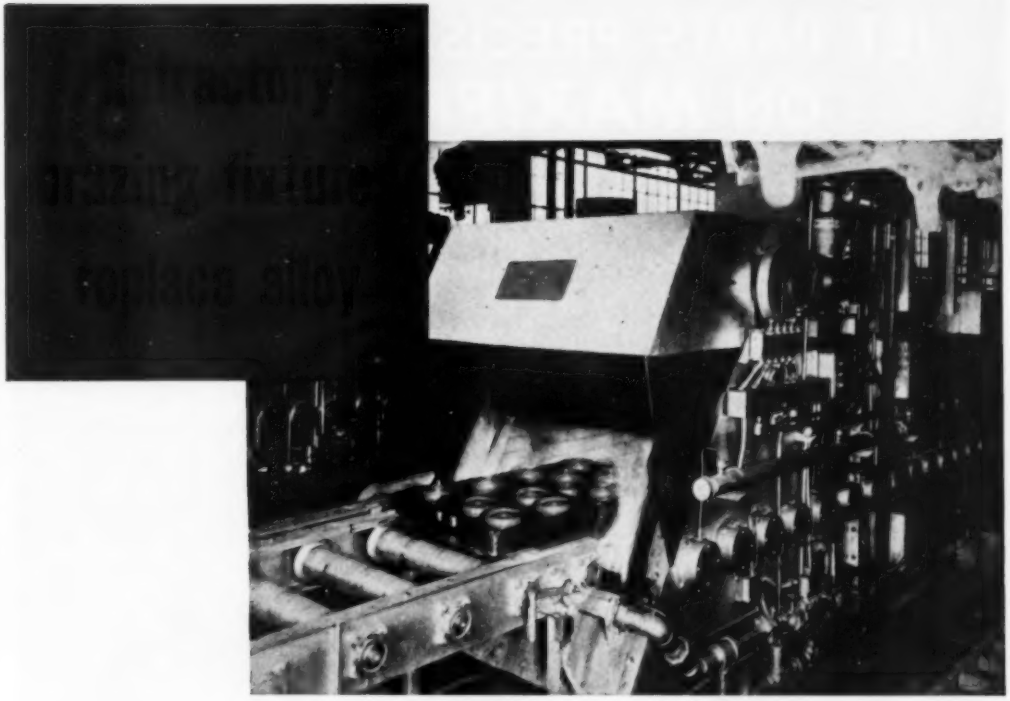
CLOSE TEMPERATURE CONTROL. Any change in temperature, even as small as 0.1% full scale, starts immediate control action. All pyrometer models are available in a variety of temperature ranges in the 0-3000 F span.

HIGH FLUX DENSITY is provided by a 3¼-pound alnico magnet. It also allows large air gaps. The lightweight moving system effectively resists shocks and vibration.

FOR MORE INFORMATION, call your G-E representative or write for Bulletin GEC-713. General Electric also offers a complete line of thermocouples—described in GEC-714. Write Section 602-238, General Electric Company, Schenectady, New York.

FOUR TYPES AVAILABLE—indicating, protecting, two- and three-position control forms. Both flush and surface mountings can be supplied; wide variety of temperature ranges is available.

GENERAL ELECTRIC



. . . last 5 times longer

Automotive parts go through this furnace from cold, to 2100F, to cold, in 1 hour and 10 minutes. It's brazing on a volume basis.

The fixtures holding the parts were formerly made of a special heat-resisting alloy. These warped badly, and the parts often stuck to the fixtures. Attempts to overcome the warping by making the fixtures thicker resulted in fixtures which absorbed most of the furnace heat. They also added considerable load on the roller hearth.

When replaced with CARBOFRAX silicon carbide refractory fixtures, the weight per loaded tray was nearly halved, sticking was eliminated, and the fixtures *now last 5 times longer.* The new fixtures, of course, cost far less than the alloy.

Think what these advantages add up to in terms of labor, materials and down time . . . savings you may be able to duplicate where heat resistant metals are used in furnaces (e.g. skid rails, muffles, radiant tubes, roller hearths, etc.). For further data address Dept. C-72, Refractories Div., The Carborundum Co., Perth Amboy, N. J.

Use Super Refractories by

CARBORUNDUM

Trade Mark

"Carborundum" and "Carbofrax" are registered trademarks which indicate manufacture by The Carborundum Company.

JET PARTS PRECISION-FORGED ON *MAXIPRESSES!*

• **The forging of compressor blades and turbine buckets for jet aircraft engines demands the unparalleled ruggedness designed and built into the *new* MAXIPRES.**

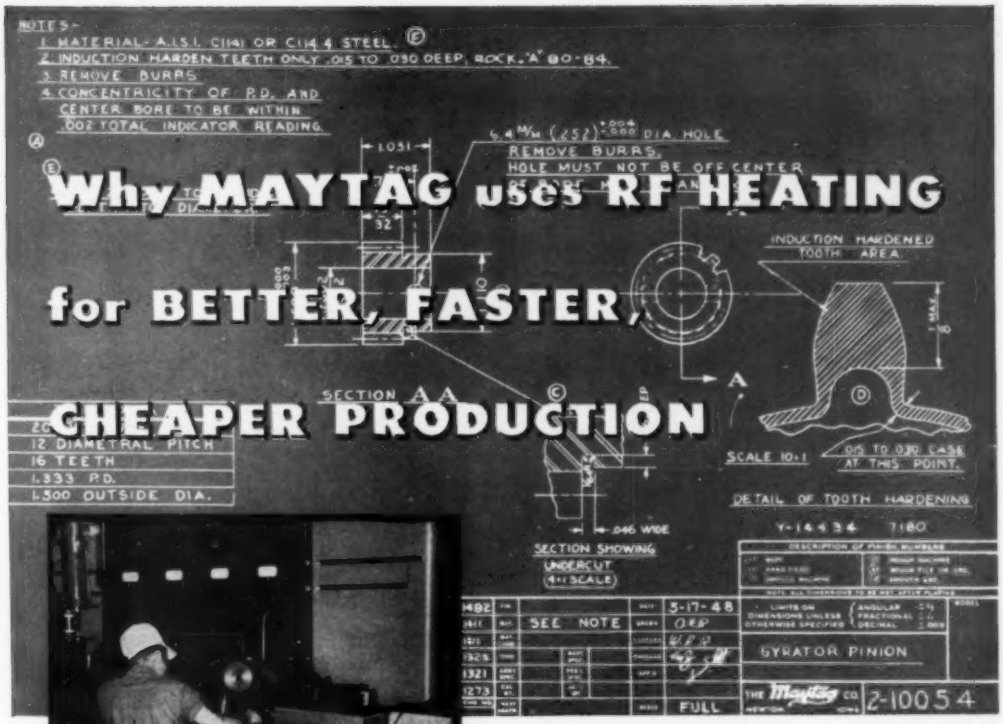
For this reason MAXIPRESSES are being chosen for the vast portion of the American, Canadian and British jet forging installations.

These fine, newly redesigned, high speed forging presses, embodying 23 new features, are specially suited to the most difficult present-day work, and by the same token will be the most reliable forge-shop equipment for future use as well.

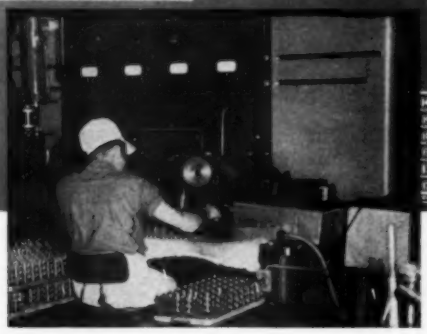
NATIONAL
MACHINERY COMPANY
TIFFIN, OHIO — SINCE 1874

DESIGNERS AND BUILDERS OF MODERN FORGING MACHINES • MAXIPRESSES • REDUCEROLLS • COLD HEADERS • BOLTMAKERS • NUT FORMERS • TAPPERS • NAILMAKERS

Hartford Detroit Chicago



Why MAYTAG uses RF HEATING for BETTER, FASTER, CHEAPER PRODUCTION



● The Maytag Company has found, for fast production at low cost and high quality, Westinghouse RF Heating installations are the answer.

The installation of a process using two 20 KW-450 generators—for both spline and straight shaft hardening—has paid for itself in *less than 3 months!* This was shortly after World War II, and since then continued use has piled up real profit in savings.

In building a new plant for production of a completely new line of automatic washing machines, Maytag turned to induction heating for brazing and hardening . . . and they specified Westinghouse. A 50 KW and 10 KW RF generator, with associated work handling equipment, are now accounting for still further savings and continued high quality. That's why Maytag says that not only is the Westinghouse RF process the best method for heat treating production parts, but, also, "it produces precision work at the price of rough and ready work."

As we helped Maytag, let us help you solve your problems of increased production at low cost and with high quality. By all means, investigate the possibilities of installing Westinghouse RF Heating.

J-02341

Westinghouse Electric Corporation
Department P-41
2519 Wilkens Avenue · Baltimore 3, Maryland

Send me your informative case history booklet on induction heating.

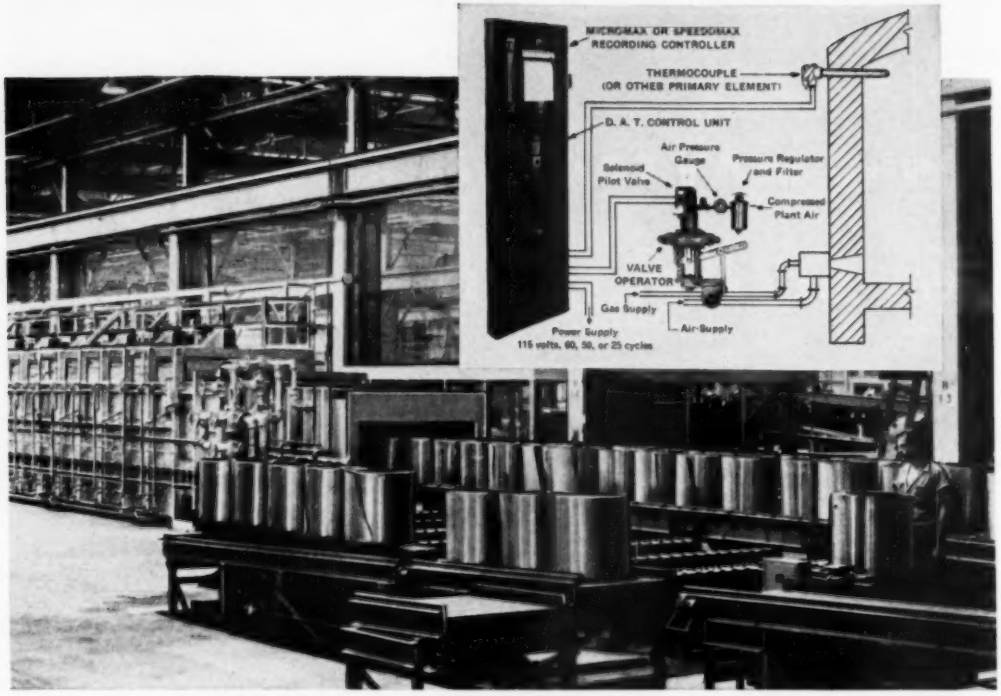
Name .....

Company .....

Street .....

City ..... Zone ..... State .....

INDUCTION HEATING



THIS "package" OF CONTROL FITS ITSELF TO FURNACE NEEDS

. . . and only L&N can supply all its features!

• Scovill Manufacturing Company credits pyrometric control of their 119-foot annealing furnaces with a big part in helping to produce the most uniform, high-quality brass they've ever made. Each furnace anneals sheet in 2000 lb. coils and has a capacity of 32,500 lbs. per hour. The four furnaces were built by Surface Combustion Co. and The Electric Furnace Co. for Scovill's 10 million dollar continuous strip mill.

Scovill's success in controlling temperatures is timely because it shows what can be done with thousands of other industrial furnaces. Small units may need only one instrument, instead of Scovill's five per furnace.

But the principle is the same.

Instead of arbitrarily turning fuel "on" at a predetermined low temperature, and "off" at a predetermined high, D.A.T. alternately turns heat on and off—flexibly adapting the periods of on-time to the needs of the furnace. When temperature begins to rise above the set-point, the periods of on-time become shorter. When temperature falls, periods of on-time grow longer. In this way, D.A.T. exactly adapts its action to the upsets, load changes and lags of the furnace. This means it holds temperature in line for all normal changes in furnace charge, ambient temperature, temperature control point, etc.

Increased production resulting from unusual uniformity is the great advantage of D.A.T. but other points are worth remembering:

Fuel can often be saved because less heat is lost up the stack.

Valve and burner sizes are not particularly critical.

D.A.T. can often modernize an old furnace, because it's so easy to install.

D.A.T. operates equally well on furnaces of full-muffle, semi-muffle, open firing and conventional radiant-tube design.

D.A.T. is just one of several L&N Controls. Call us for service or information in selecting equipment for any temperature-control problem. Address nearest office or 4927 Stenton Ave., Philadelphia 44, Penna.

LEEDS & NORTHRUP

instruments • automatic controls • furnaces

Jrl. Ad N-33A-626(7)

TYPICAL RESULTS OF BRIGHT, SCALE-FREE WORK THE "IPSENWAY"

1. CLUTCH PRESSURE PLATE
Carbonitrided, 300 per heat, to case depth of .005" — .007" in cycle time of 60 minutes.

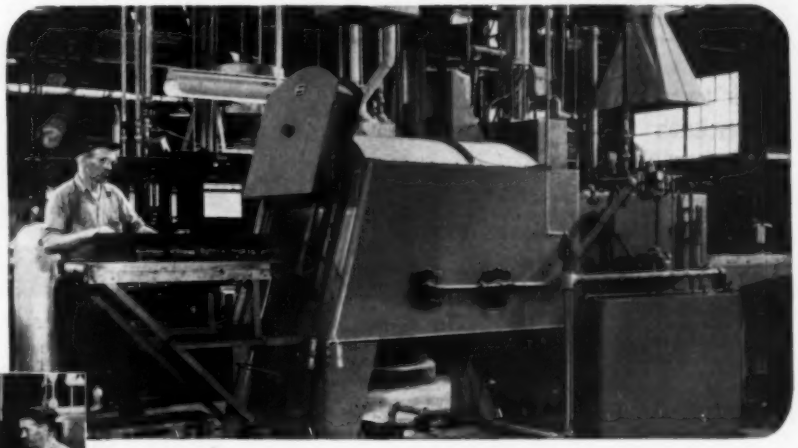
2. BREATHER VALVE GEAR
Carbonitrided, 250 pieces per heat, to case depth of .010" — .012" in cycle time of 95 minutes.

3. FENDER HINGE SEGMENT
Carbonitrided, 750 pieces per heat, to case depth of .010" — .012" in cycle time of 90 minutes.

4. ROLLER TAPPET ASSEMBLY
Carbonitrided, 800 pieces per heat, file hard case, in cycle time of 60 minutes.

PRODUCTION SHORT-CUTS *in Heat Treating*

AT HARLEY-DAVIDSON MOTOR CO., MILWAUKEE



View of Ipsen T-250 Unit in operation at Harley-Davidson. Loading door is hydraulically operated by foot pedal. Trays are transferred from heat through intermediate door into quench or cooling chamber automatically.

Unloading view showing parts after oil quenching operation. Oil is automatically circulated and temperature controlled, assuring uniform cooling throughout load.

...with an IPSEN Standard AUTOMATIC HEAT TREATING UNIT

Illustrated above are typical heat treating results obtained by Harley-Davidson Motor Co., Milwaukee, in processing parts automatically in a standard Ipsen Heat Treating and Quenching Unit. Individual methods are applied for each part to suit material and depth of hardness desired. The operation in the Ipsen is automatically controlled from heat through quench (or cooling) so that highly uniform, dependable results are obtained from batch to batch.

Acid Cleaning and Extra Handling Eliminated

Because each load is heat-treated at a uniform temperature and in a controlled and sealed atmosphere condition, the work comes out bright and scale-free. This, in turn, eliminates acid cleaning operations and extra handling. In addition, clean working conditions prevail, and unskilled operators can be quickly and easily trained to tend several units simultaneously. Investigate this modern, simplified method of heat treating today.

Write **TODAY FOR MORE FACTS**

Ask for free bulletins and find out how Ipsen Units can be applied to your work. If you wish, samples of your work will be run, procedures established, and production estimates made without obligation.

IPSEN INDUSTRIES, INC., 723 South Main Street, Rockford, Illinois

Production units for CARBONITRIDING · CARBURIZING · HARDENING · BRAZING · MARTEMPERING

UNICHROME
Trade Mark

News about
COATINGS for METALS
Metallic . . . . . Organic . . . . . Decorative . . . . . Protective

Unichrome S.R.H.S. Chromium Solution works a
Big Improvement in Hard Chromium Plating

Lower temperature copper bath usable in nickel tanks

Especially important to the plater substituting copper for nickel is the fact that Unichrome Pyrophosphate Copper Bath, operating at only 110° to 140° F, can be used in nickel tanks with rubber or plastic linings.

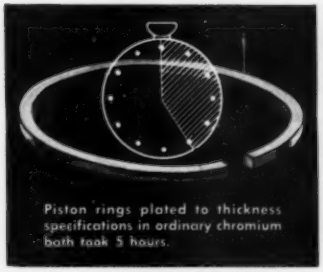
Saving the cost of converting the tank is not the only benefit. The Unichrome Copper Process maintains a wide plating current range, and without brighteners, deposits a smooth plate excellent for direct plating with chromium. It contains no cyanide to dispose of. Bulletin CU-2 gives more data.

EFFICIENT INSULATION ASSURES MORE EFFICIENT PLATING

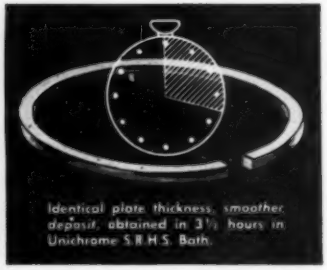
Use of proper insulations not only improve plating results but also saves current and metals. Unichrome Stop-Off Compounds and Lacquers are noted for ease and economy of application on the work to be plated; Unichrome Coating 218X for the long lasting protection it gives to racks despite the toughest plating and cleaning cycles.

Tantalum Coils Last and Last

Installing a Unichrome Heating Coil or Heat Exchanger with tantalum tubes is good economy. Giving trouble-free service in acid baths for remarkable periods of time, the tantalum virtually eliminates maintenance, downtime and loss of valuable plating production. At one plant, a tantalum coil has already seen 4 years of service and is still as good as the day installed.



Piston rings plated to thickness specifications in ordinary chromium bath took 5 hours.



Identical plate thickness, smoother deposit, obtained in 3½ hours in Unichrome S.R.H.S. Bath.

■ There's a big difference in the hard chromium plating operations of many plants nowadays. It has been simplified, speeded up, and consistently better results assured — all through installation of the Unichrome S.R.H.S. Chromium Bath. The improvements reveal themselves in many ways.

A REAL GAIN IN OUTPUT

Especially in hard chromium plating, where it often takes many hours to deposit the specified thickness of chromium, the higher plating speed of S.R.H.S. Chromium works wonders. Cutting plating time by 20 to 50%, it helps to boost production without extra equipment. For example, piston ring plating takes 3½ hours now, instead of the 5 it used to at one plant. Another plant plates .005" of chromium on steel bushings in 2½ to 3 hours — half the usual time — by using a Unichrome S.R.H.S. Chromium Bath. And the deposit is smoother, too.

MANY PRODUCTION ADVANTAGES

Unichrome S.R.H.S. Chromium Solution deposits chromium with less "treeing". Its "leveling action" also assures a smoother plate. Both these features mean less need to deposit excess chromium to allow for grinding and final finishing—thereby saving additional plating and production time.

As a self-regulating bath, Unichrome S.R.H.S. Chromium not only minimizes control problems, but also maintains top throwing power and reduces rejects.

LOSS OF FATIGUE STRENGTH MINIMIZED

Chromium plating is known to reduce fatigue strength of steel. Recent research has proved, however, that parts plated in the Unichrome S.R.H.S. Chromium Bath have the smallest loss of fatigue strength. Here are some results on heat-treated test specimens plated with 0.001" of chromium as reported by an independent laboratory:

Chromium Plating Solution	Fatigue Strength psi	% Loss Over Unplated
Unplated	81,500	—
Ordinary	60,500	25.7
SRHS CR-100	75,200	7.7
SRHS CR-110	75,300	7.6

* * *

Write or phone the nearest United Chromium office for more information on getting better chromium plate for defense or industrial applications. Electroplating engineers will be glad to show you how you can meet specifications in less time and with less trouble by means of the S.R.H.S. Chromium Bath.

UNICHROME
Trade Mark

UNITED CHROMIUM, INCORPORATED
100 East 42nd Street, New York 17, N. Y.
Detroit 20, Mich. • Waterbury 20, Conn.
Chicago 4, Ill. • Los Angeles 13, Calif.
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United Chromium Limited, Toronto, Ont.

NORGE ENGINEERS SAY...

STRESSPROOF® WORKS WHERE OTHER STEELS FAIL

STRESSPROOF was selected for this transmission pinion gear for the Norge washing machine—made by NORGE Division of Borg-Warner Corporation.

● This washing machine pinion must run for years without appreciable wear. After extensive field tests, Norge engineers found that STRESSPROOF works where other steels fail. Even heat-treated alloy, at double the cost per part, does not equal STRESSPROOF.

Then too, STRESSPROOF is used as machined. No heat treating means no distortion, with the consequent noisy operation of the washing machine. The pinions made of STRESSPROOF are clean and free of scale and require no clean-up work. They are ready for assembly as they come off the machines.

STRESSPROOF makes a better part at lower cost.

Wear resistance is only one of the four in-the-bar qualities that makes STRESSPROOF the choice for thousands of parts. *High strength*, double that of ordinary cold-finished shafting; *Machinability*, fully 50% better than heat-treated alloys of the same strength; and *Minimum warpage* in machining—are three other attributes of this unique steel.

SEND FOR Free Engineering Bulletin "New Economies in the Use of Steel Bars."

La Salle **STEEL CO.**

... the Most Complete Line of Carbon and Alloy Cold-Finished and Ground and Polished Bars in America.

La Salle Steel Co.
1424 150th Street
Hammond, Indiana

Please send me your STRESSPROOF Bulletin.

Name_____

Title_____

Company_____

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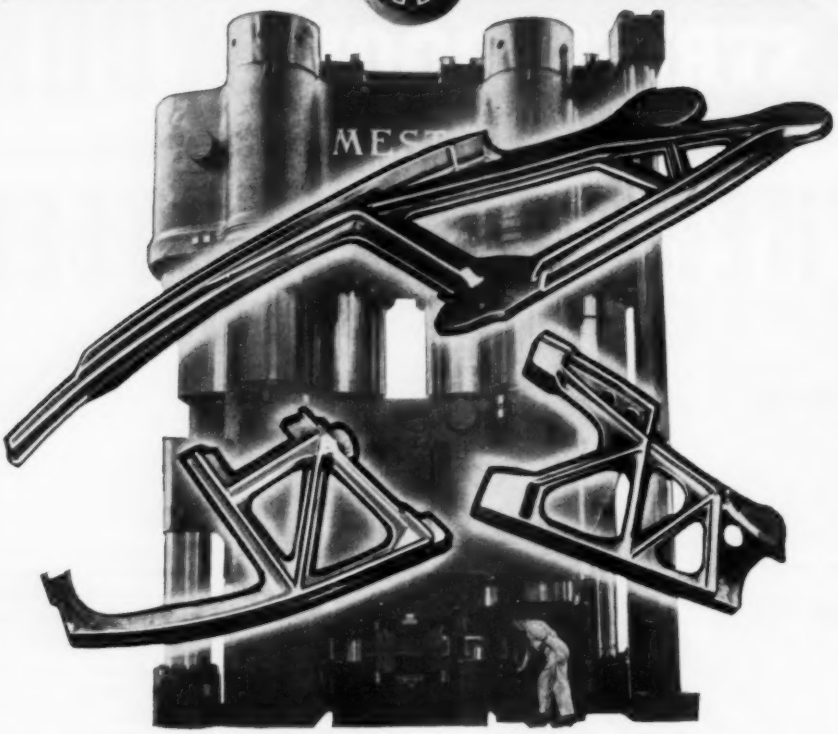


Greater Size and Speed in Aircraft have created engineering problems, the solution of which has required larger and larger forgings of high-strength aluminum alloy. *Examples* shown above are forged structural members used in a modern military bomber, the largest more than seven feet over all. These are forged on an 18,000-ton press, the biggest ever built in this country.

Wyman-Gordon Experience—the most extensive in the industry—is keeping abreast of new forging demands involving the use of Steel, Aluminum, Magnesium, High Density Alloys and Titanium.

• • •

Standard of the Industry for More than Sixty-five Years

WYMAN-GORDON

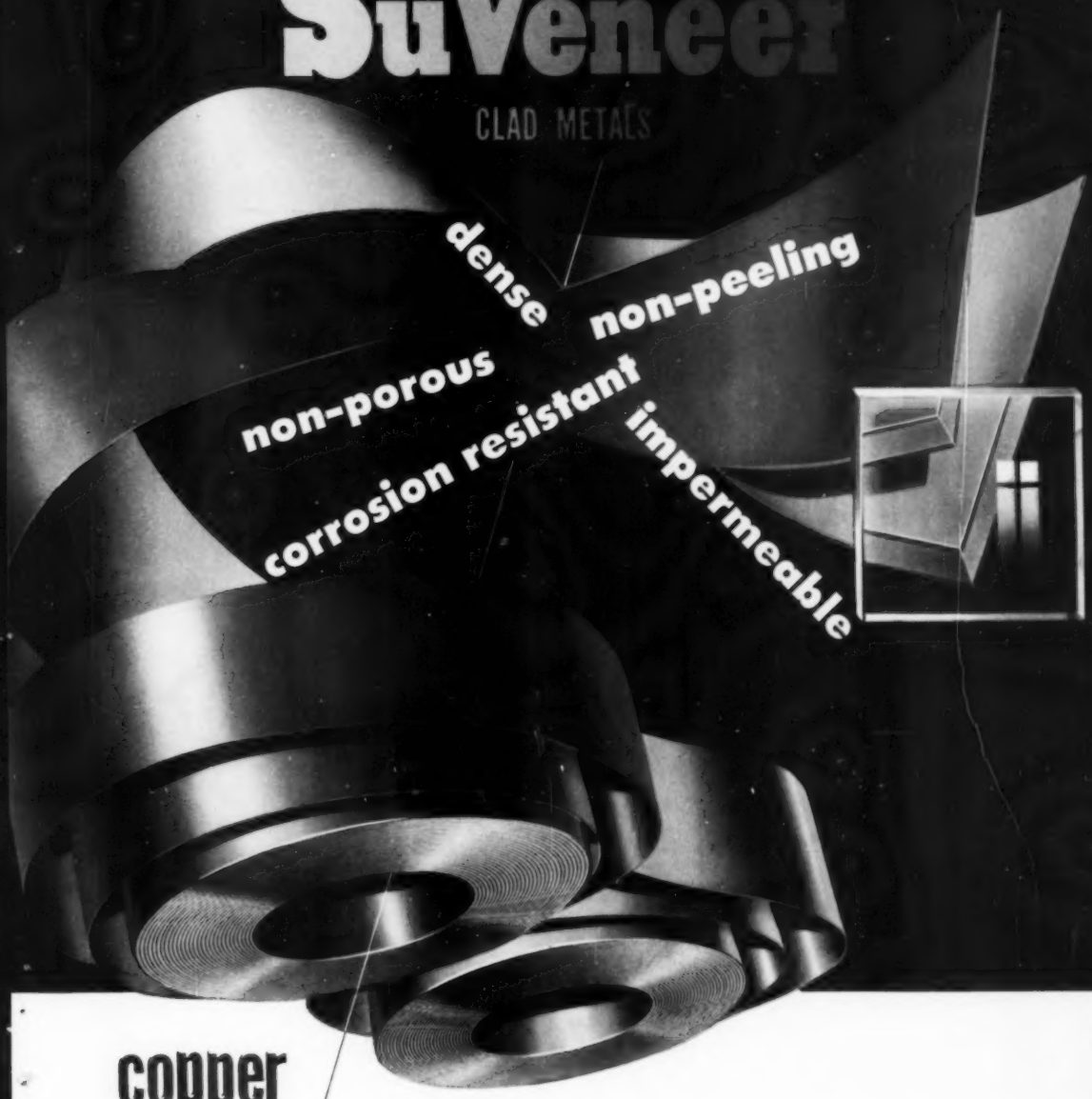
FORGINGS OF ALUMINUM • MAGNESIUM • STEEL

WORCESTER, MASSACHUSETTS

HARVEY, ILLINOIS DETROIT, MICHIGAN

SuVeneer

CLAD METALS



copper

or **brass** bonded inseparably to low carbon steel

Here is your answer to the need for conserving critical metals: **SuVeneer** Clad Metals save up to 80% of solid copper or brass, while giving you every surface advantage of these strategic materials in your products. Actual copper or brass face one or both sides of the steel strip, in constant thickness-ratio for all strip gauges. Fabricate **SuVeneer** Clad Metal any way you like—the bond is mechanically inseparable—the production behavior is excellent! *We'll gladly advise you on your applications, without obligation.*

Superior Steel
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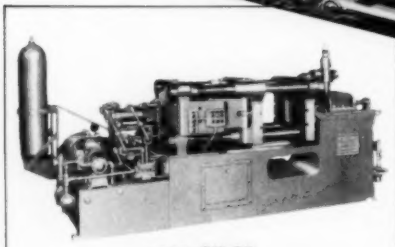
KUX

FIRST NAME IN DIE CASTING MACHINES

HELPS MAKE HUBLEY
FIRST NAME IN ACTION TOYS



MODEL BH-30
Hydraulically operated die casting machine for production of zinc castings weighing up to 10 pounds.

THE TEXAN

Boys hate to be called, "sissy". To prove they're not, they go to great lengths to be rough and tough. That means their toys, too, have to be rough and tough. Hubley Manufacturing Company, by using KUX die casting machines in the manufacture of its "Texan" Repeater Pistol, gets that extra ruggedness necessary in producing toys that last.

WHAT ABOUT YOUR PRODUCT? Does it stand up to the treatment it has to take? KUX die casting machines can tremendously improve its quality and saleability. Call KUX now! Let us show you how!

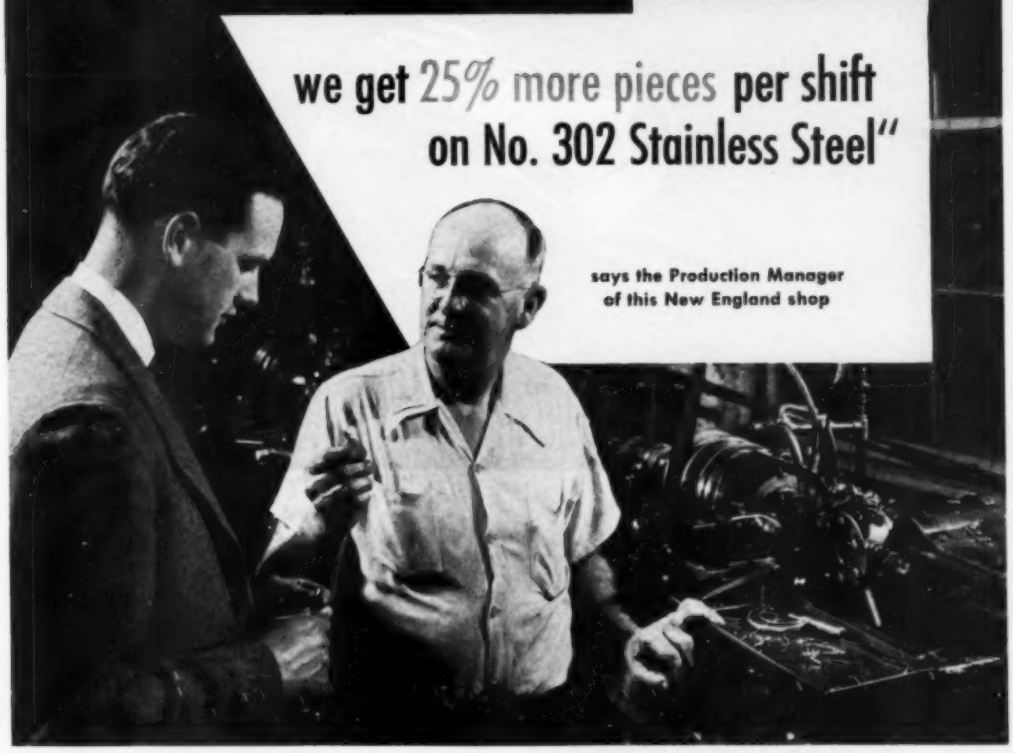
KUX MACHINE COMPANY • 6725 N. Ridge, Chicago 26, Illinois

KUX

FIRST NAME IN DIE CASTING MACHINES
SELECTED BY FIRST NAMES IN INDUSTRY

"With GULF LASUPAR Cutting Oil

we get 25% more pieces per shift on No. 302 Stainless Steel"



says the Production Manager of this New England shop

"TOOL LIFE on A.I.S.I. No. 302 Stainless Steel parts was such a problem that our production costs were well below the break-even point," says Roy Groth, Production Manager, Groth Manufacturing Company, Plainville, Conn. "Since we switched to Gulf Lasupar Cutting Oil, we increased tool life from 1½ to 8 hours. As a result, instead of 400 pieces per shift, we're producing 500, an increase of 25%."

This is typical of results obtained with Gulf Lasupar Cutting Oil in scores of modern machine shops. Here are the important reasons why: Gulf Lasupar Cutting Oil contains sulphur combined by a special Gulf process which provides greater chemical activity over the entire range of a cutting operation. This means better protection for the tool.

Gulf Lasupar Cutting Oil also contains stable sulphurized fatty oil, effective in producing the fine finishes for which this quality cutting oil is so well known.

Operators like it because they get these production advantages without the disagreeable odor ordinarily associated with sulphurized cutting oils.

Ask a Gulf Lubrication Engineer to demonstrate in your shop the advantages of Gulf Lasupar Cutting Oil and other quality cutting oils in Gulf's complete line. Write, wire, or phone your nearest Gulf office today. Or send the coupon below.

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719 Gulf Building, Pittsburgh 30, Pa.

Please send me, without obligation, a copy of your new pamphlet "Gulf Lasupar Cutting Oil."

Name .....

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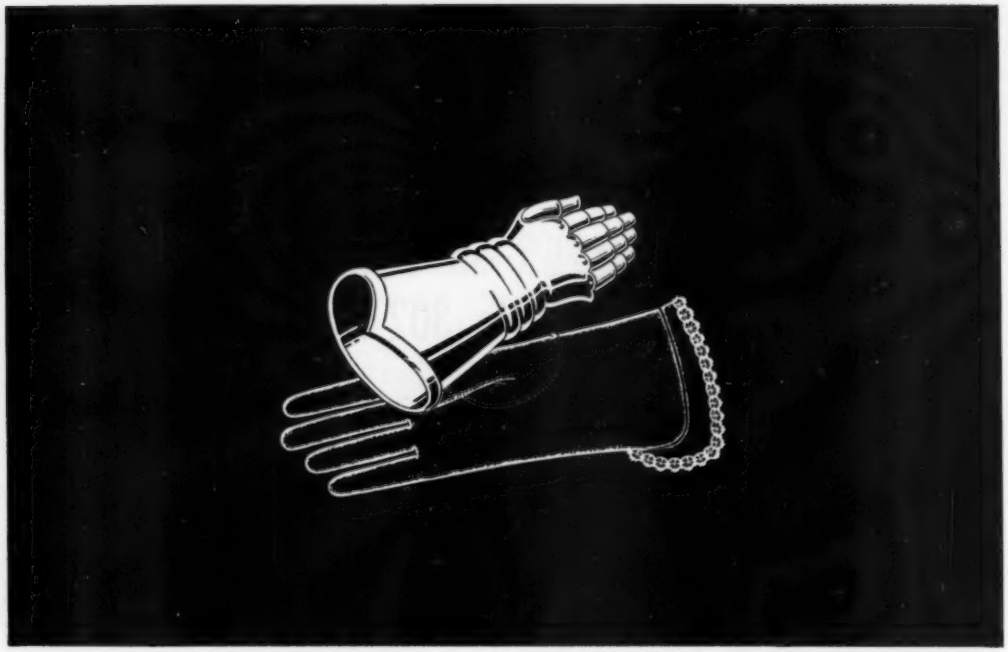

THE IRON FIST IN A *Velvet Glove*

Supposing—just supposing—YOU could write the specifications for an ideal blastcleaning chilled shot and grit. What qualities would you specify? You'd want it to be hard, of course, so it would clean fast. But you wouldn't want it so hard as to wear out your equipment at a rapid rate. Neither would you want the shot to be hard AND BRITTLE.

The ideal chilled iron shot and grit would be hard enough to do a fast cleaning job. And, if possible, you would want the hard iron carbides (that do the cutting) imbedded in some soft material that would go easy on your equipment and keep the shot from shattering into small ineffectual fines. What you would want is a sort of an "iron fist in a velvet glove" kind of shot and grit.

It may come as a surprise to you that there *is* such a shot and grit made. A chilled iron shot that holds the iron carbides in a *ductile matrix*—a shot that is hard enough to clean fast, yet soft enough to spare equipment and keep the shot from shattering too quickly. It is National Controlled "T" Shot and Grit.

We're not going to make any wild claims—we know YOU can appreciate the advantages of such shot and grit—providing what we say is true. And we'd like to prove our case *in a matter of minutes*—if you'll let us. Please write your name and address on the lines below and mail the coupon to the nearest Hickman-Williams office. The most you can lose is the cost of postage, but you may profit to the tune of a substantial sum of dollars.

NATIONAL CONTROLLED "T" SHOT AND GRIT *IS PRODUCED EXCLUSIVELY BY*
NATIONAL METAL ABRASIVE COMPANY • CLEVELAND, OHIO
WESTERN METAL ABRASIVES COMPANY • CHICAGO HEIGHTS, ILL.
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OK. Let's see you prove your point . . .

Name_____

Firm_____

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MAIL TO HICKMAN, WILLIAMS OFFICE NEAREST YOU

2 ways to ease your Steel Shortage

1 Collect all dormant Steel Scrap and get it to the steel producers

Millions of tons of valuable scrap still lie idle in America. Scrap salvage means more production—a stronger America. Clean out your plant . . . sell all your iron and steel scrap to your local scrap dealer now. The need is urgent. Every bit will help to meet the needs of defense production.

2 Make your steel supply go farther —specify N-A-X HIGH-TENSILE STEEL

Users of N-A-X HIGH-TENSILE steel find they can make 3 tons do the work of 4. Through its high strength and corrosion-resistant properties, lighter sections can be used without sacrifice of quality. It fabricates and welds with the ease of mild carbon steel. Let us assist you in applying this economy to your products.

GREAT LAKES STEEL CORPORATION

N-A-X Alloy Division — Ecorse, Detroit 29, Mich.

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Match your x-ray diffraction needs exactly from the complete GE line

X-ray diffraction is industry's most versatile method of analyzing materials. To make your investigations easier, faster, more exact — General Electric offers two x-ray diffraction units in its XRD line, with four standard combinations of components to meet all diffraction requirements. For complete information, see your GE x-ray representative, or write X-Ray Department, General Electric Company, Milwaukee 1, Wisconsin, Rm. AS-7.

You can put your confidence in —

GENERAL ELECTRIC

For direct measurement of diffracted intensities. XRD-3D provides quantitative analysis of solid crystalline materials. As in all XRD units, appropriate accessories can readily be added for other technics.

For direct measurement of fluorescent x-ray spectra. The XRD-3S permits rapid quantitative analysis for chemical elements whose atomic number is greater than 22.

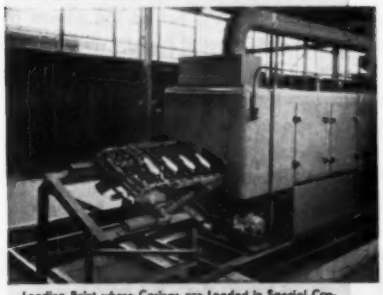
For diffraction with film technics. The XRD-4 has vertical x-ray tube axis that provides three ports for all common diffraction cameras.

For diffraction with film technics. The XRD-3F is intended for laboratories anticipating the inclusion of components for direct measurement of diffraction effects.

COMPLETE *Finishing* SYSTEMS

. . . for ENAMELS • LACQUER • PAINT • VARNISH

Projectile Casings Emerging from Dry-Off Oven at Cleveland Welding Company's Plant and Receiving Coat of Paint on Interior Surfaces in Semiautomatic Painting Machine.



Loading Point where Casings are Loaded in Special Conveyor Adapters at Entrance End of the Five-Stage Cleaning and Bonderizing Machine.

Equipment for Military Paint Specifications . . .
Processing Equipment for Cold Extrusion Operations!

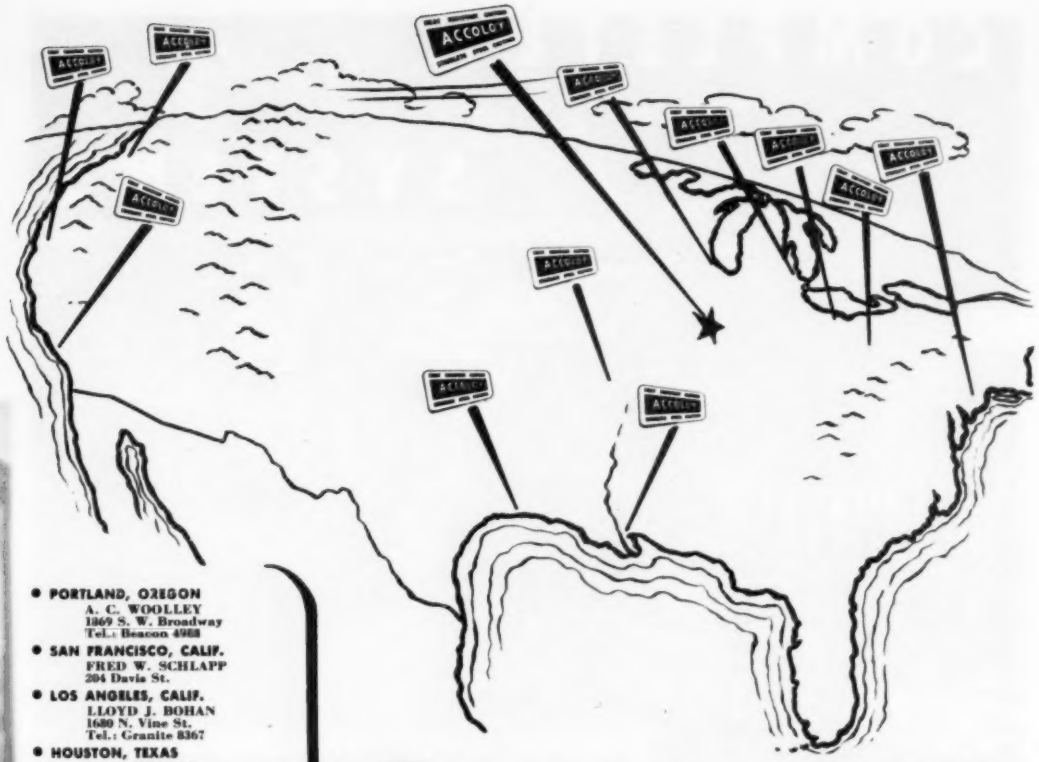
Illustrated here you see a Complete Mahon Finishing System for automatically coating the inside and outside of projectile casings. The system includes a five-stage Metal Cleaning and Bonderizing Machine, a Dry-Off Oven, a semi-automatic interior Spray Coating Machine and a Hydro-Filter Spray Booth equipped with an adapter rotating device and automatic spray guns for coating the exterior of the casings. If you are in need of equipment to meet Military Specification JAN C-490 Grade No. 1, or PA-PG 191, the Mahon Company has already installed many complete systems and are thoroughly familiar with these requirements. Mahon engineers have also produced equipment for processing projectile cartridge cases, as well as complete equipment for Pickling, Bonderizing, and application of drawing solutions in connection with cold extrusion operations. When you turn your equipment problems over to Mahon, you immediately enlist the services of the best qualified engineers in this field . . . engineers with a background of experience and a wealth of technical knowledge and practical know-how not available to you elsewhere. See Sweet's Mechanical Industries File, or write for Catalog A-652.

THE R. C. MAHON COMPANY

HOME OFFICE and PLANT, Detroit 34, Mich. • WESTERN SALES DIVISION, Chicago 4, Ill.

Engineers and Manufacturers of Complete Finishing Systems—including Metal Cleaning and Pickling Equipment, Metal Cleaning and Rust Proofing Equipment, Dry-Off Ovens, Hydro-Filter Spray Booths, Filtered Air Supply Systems, and Drying and Baking Ovens; Core Ovens, Hydro-Foam Dust Collectors, Dust Traps, Fog-Filters, and other Units of Special Production Equipment.

MAHON



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Leadership of a product is determined by the service and quality it renders. ACCOLOY, with its reputation for ENGINEERING, DESIGN and MANUFACTURE of Heat and Corrosion Resistant Castings, has these men strategically located across the nation to uphold that position as leader. Call the nearest ACCOLOY Engineer who *CAN* and *WILL* show you how ACCOLOY castings definitely show an increase in profits on your production line.

Accoloy Castings . . . "Preferred by Industry!"

HEAT RESISTANT CASTINGS
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STAINLESS STEEL CASTINGS

ALLOY ENGINEERING & CASTING COMPANY

ALLOY CASTING CO. (Div.)

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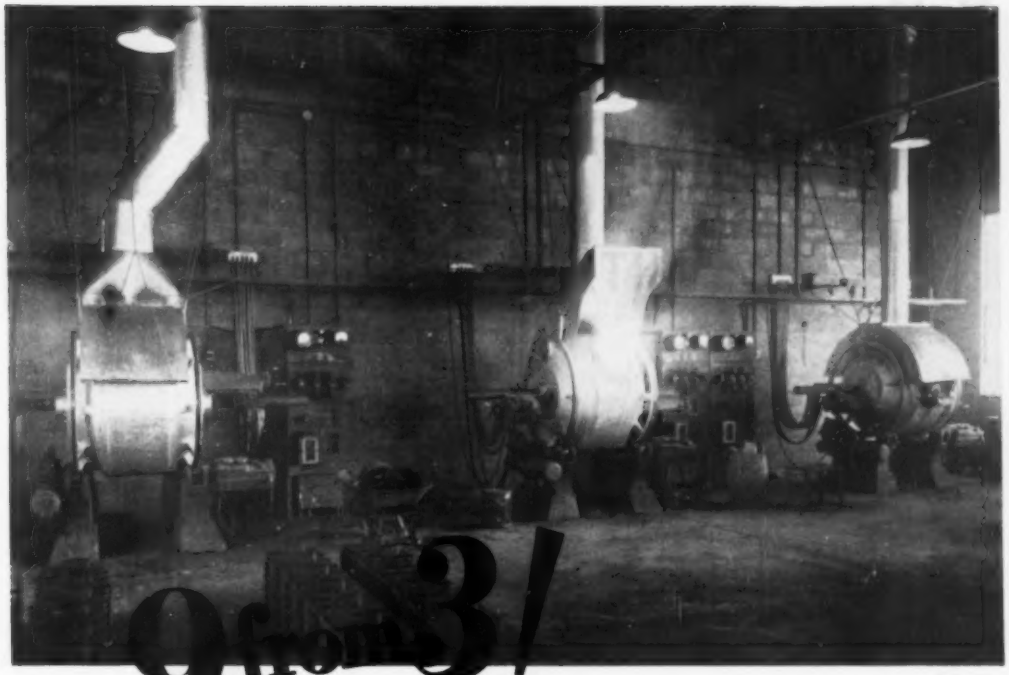
ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS



NINE TONS OF HIGH QUALITY IRON PER SHIFT FROM THESE 3 DETROIT ROCKING ELECTRIC FURNACES

Vassar Electroloy Products Company has based its growth on precisely controlled, quality iron and steel castings. In five years, metal melting requirements have increased more than 700%.

Today, three 700-lb. Detroit Rocking Electric Furnaces keep the pouring ladles full, producing alloys with exact metallurgical and physical characteristics melt after melt. The fast, efficient operation of these furnaces maintains high production levels and high standards of economy.

For melting ferrous or non-ferrous metals, these indirect arc furnaces have many advantages; easy, positive control; uniformity of melts; thorough mixture of elements through the melts; optimum use of power; less metal shrinkage; more heats per day; easy shell replacement.

Furnaces are available in 10 to 4,000 lbs. capacity, designed specifically to fit your electrical specifications. Get full information. Write today!

Tapping a heat of alloy steel from Detroit Rocking Electric Furnace at Vassar Electroloy Products Co. Furnace is Type LFY, 700 lb., 175 Kw.

DETROIT ELECTRIC FURNACE DIVISION

KUHLMAN ELECTRIC COMPANY, BAY CITY, MICHIGAN

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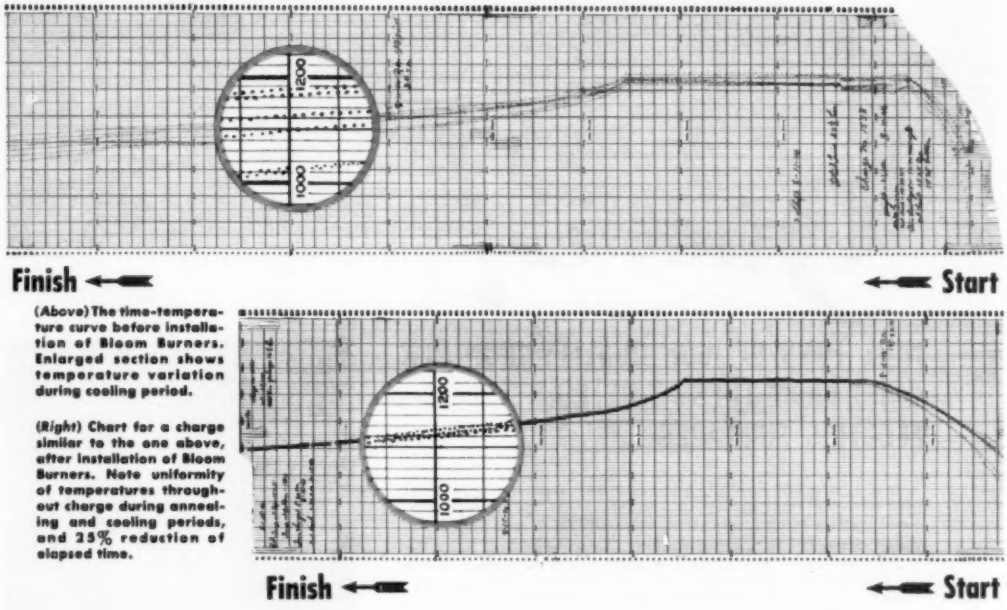
FEMA

Uniform Temperatures and Faster Heating WITH BLOOM



(Above) The time-temperature curve before installation of Bloom Burners. Enlarged section shows temperature variation during cooling period.

(*Right*) Chart for a charge similar to the one above, after installation of Bloom Burners. Note uniformity of temperatures throughout charge during annealing and cooling periods, and 25% reduction of elapsed time.

The time-temperature curves above show how Bloom Tempered Flame Burners maintain uniform temperatures throughout the charge, and improve furnace operation and output. They represent two similar annealing heats for a car-type annealing furnace, one before and the other after Bloom Burners were installed.

The upper curve shows a test run previous to the change-over. Variation throughout the charge at the annealing temperature was from 1440 to 1540 degrees F., and at finish, it ranged from 840 to 1040 degrees F.

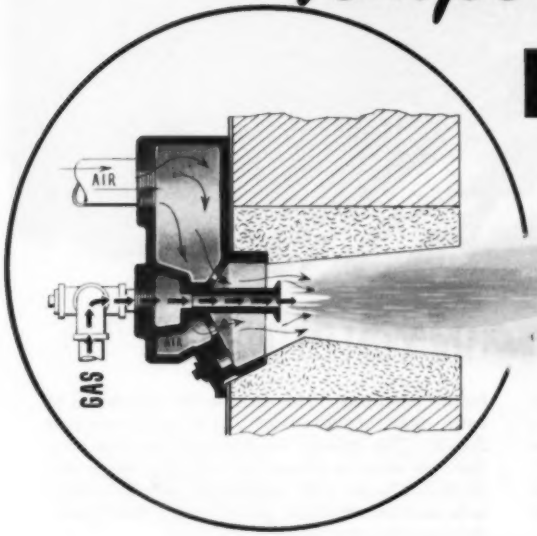
After installing Bloom Burners, the temperatures were held to within plus or minus 10 degrees F. for a similar charge, and the elapsed time was reduced 25 per cent.

The unique design of Bloom Tempered Flame Burners permits operation with a high per-

ENGINEERED

Tempered Flame

BURNERS

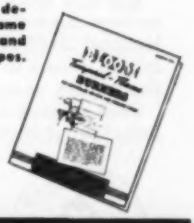


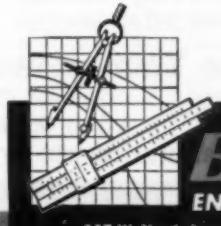
The Bloom Tempered Flame Burner is available in a wide range of capacities. The cross-section view above shows a typical burner.

centage of excess air. The burners operate with flame temperature only slightly higher than that required by the charge. Consequently hot and cold spots within the furnace chamber are eliminated, and the charge is heated uniformly. Five years of experience in a variety of applications have demonstrated the ability of these burners to increase furnace production, reduce costs and improve quality of product.

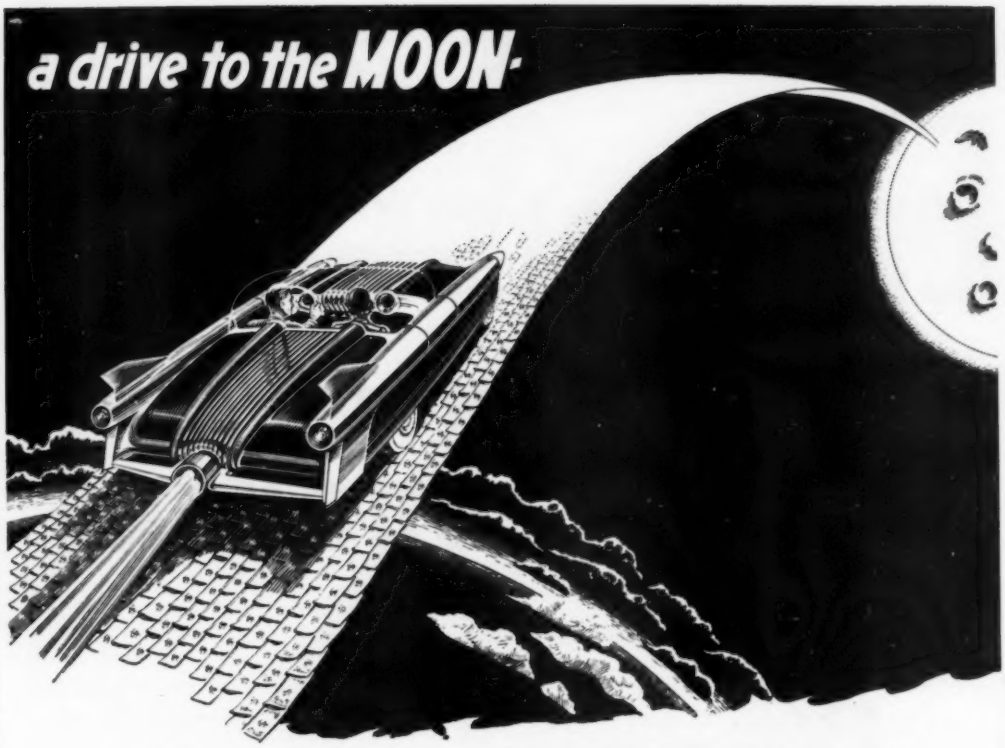
Write

for bulletin 1220-5, which describes Bloom Tempered Flame Burners. It gives dimensions and capacities for the various types.





BLOOM
ENGINEERING CO., INC.
857 W. North Avenue Pittsburgh 33, Pa.



On a road paved with YOUR Dollars

A road twenty feet wide, carpeted with one dollar bills, extending 256,471 miles through space to the moon,--illustrates the astronomical magnitude of our Federal debt.

1932 was a bad year for most of us, whether we were in business, or looking for a job, or going to school.

1952 seems much better to the majority of our citizens, with increased business, high wages and a good education for the children.

But how much better off, really, are those of us who think "we're in clover"? Consider our National debt which has skyrocketed from 19 billion dollars to over 260 billion dollars in the past twenty years.

Such a figure is difficult to grasp. But it represents your debt, the amount that you and your family must pay. This debt is the obligation of every man, woman and child in the United States. The interest on this debt must be paid through taxes, and as the debt increases, the more our taxes will increase. If you have a wife and two children, your share of the Federal debt is now approximately $7,000.

Your debt is now 13 times what it was in 1932, and they're planning right now, down in Washington, to inflate it even more.

Do you like it? Is that what you want? If you don't like it and don't want further expansion of our Federal debt, it's up to you to let Washington know. Only when American citizens are aroused and speak up, by electing able and patriotic men to public office, will there be an end to this orgy of public extravagance.

YOUR SCRAP YOUNGSTOWN IS NEEDED

The Youngstown Sheet and Tube Company

General Offices -- Youngstown 1, Ohio

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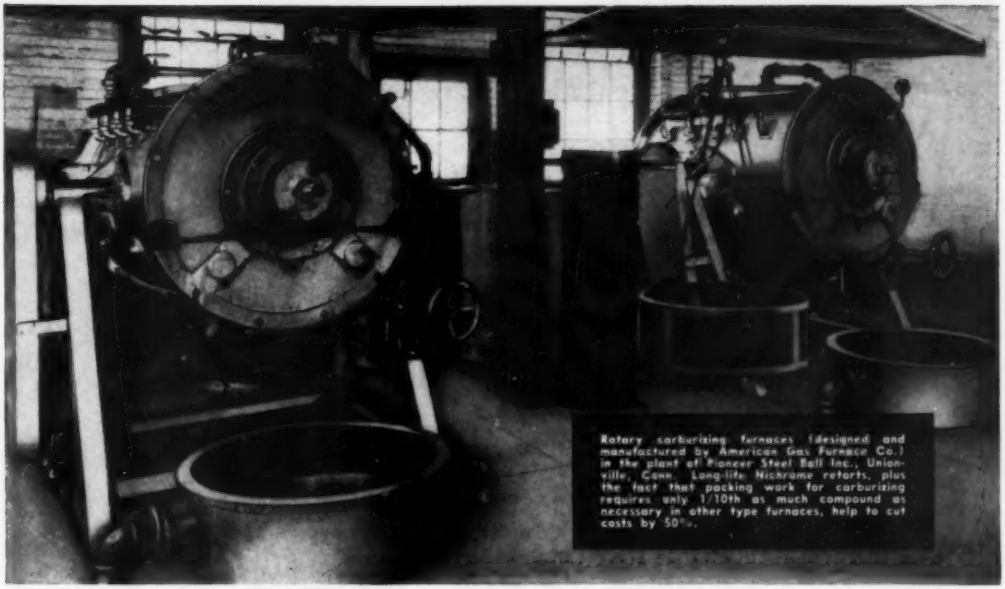
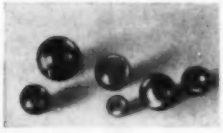
MANUFACTURERS OF CARBON ALLOY AND YOLOY STEELS

The steel industry is using all its resources to produce more steel, but it needs your help and needs it now. Turn in your scrap, through your regular sources, at the earliest possible moment.



Rotary carburizing furnaces (designed and manufactured by American Gas Furnace Co.) in the plant of Pioneer Steel Ball Inc., Unionville, Conn. Long-life Nichrome retorts, plus the fact that packing work for carburizing requires only 1/10th as much compound as necessary in other type furnaces, help to cut costs by 50%.

Handle your toughest heat-treating jobs for less with **Driver-Harris Alloys**



Nothing demonstrates the performance characteristics of furnace parts and fixtures so thoroughly as heat-treating cycles which alternate periods of high heat with fast quenching. And it is under just such conditions that furnace components made with Driver-Harris alloys show to best advantage—prove the most dependable and *economical*.

Here's a case in point: The batch-type rotary carburizing furnaces shown here are two of a battery equipped with Nichrome* retorts. Operation consists in charging each furnace with 450 lbs. of steel balls, together with carburizing compound, and bringing to a temperature of 1650°F. within 1½ hours. Individual furnaces are then held at temperature from one to several hours—depending upon the case depth required. When carburizing is completed, they are tilted to permit the work to spill out. Immediately after being emptied, they are re-charged.

On the average, each hot Nichrome retort is quenched, by having 450 lbs. of cold work dumped into it, every 3 hours—and is then brought rapidly up to 1650° again.

In spite of the high heat required by the carburizing operation, however, and the great thermal stresses created by frequent cooling and re-heating thruout the 24-hour operating day, the Nichrome retorts average over 11,000 hours of trouble-free service apiece before requiring any repairs.

Mainly because of this outstanding performance, the cost per pound of treating steel balls is the *lowest for this class of work in the industry*.

Both Nichrome and Chromax* afford ideal alloys for carburizing furnaces, not only because of their high heat- and corrosion-resistance, but because they are not susceptible to carburization—an advantage which helps tremendously to solve the maintenance problem, and thus hold down over-all costs.

In selecting *your* heat-treating equipment, it will profit you to remember the important economies afforded by Nichrome and Chromax. These alloys are at present on allocation, but we shall be glad to make recommendations based on your particular needs and serve you to the best of our ability.

Nichrome * and CHROMAX * are manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

*T.M. REG. U. S. PAT. OFF.

MAKERS OF WORLD-FAMOUS NICHROME AND OVER 80 ALLOYS FOR THE ELECTRICAL, ELECTRONIC AND HEAT-TREATING FIELDS

Why *Brass* can better serve your needs

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BRASS OR BRONZE ORNAMENTAL WORKS RETAIN THEIR LASTING BEAUTY . . .

Designers of ornamental works have long recognized the beauty of Brass and Bronze. The inherent qualities of these alloys lend themselves for the manufacture of name plates, statues, plaques, doors and the like. The architect and builder know that there is no substitute for Bronze when lasting beauty is essential.

FREE . . . Write for your copy of the 8-page Lavingot Technical Journal — Vol. 8, No. 2 — containing an article discussing "Refining Secondary Copper Alloys."

Specify—LAVIN NONFERROUS INGOT—*Quality*

Brass · Aluminum · Bronze · Zinc Base Die Casting Alloys

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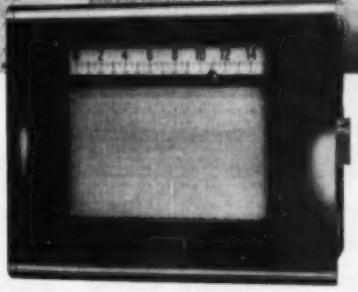
Continuous-balancing electronic recorder



The instrument makers whose advertisements appear above know that their reputations depend upon the accuracy and reliability of their recorders. They select each component part with scrupulous care.

As the recording unit in their instruments, they all selected Bristol's Dynamaster. When you choose the Dynamaster for your own measuring needs you are assured of the same accurate, precise instrumentation demanded by these instrument makers.

THERE'S A DYNAMASTER FOR EVERY NEED

Available as a bridge or potentiometer, with strip or circular charts, Dynamasters can measure any variable that can be converted into changes in d-c voltage, d-c current, resistance, or capacitance.

Dynamasters are providing accurate, trouble-free measurement and automatic control of such quantities as temperature, pressure, pH, speed, voltage, power, current, smoke density, strain, and resistance.

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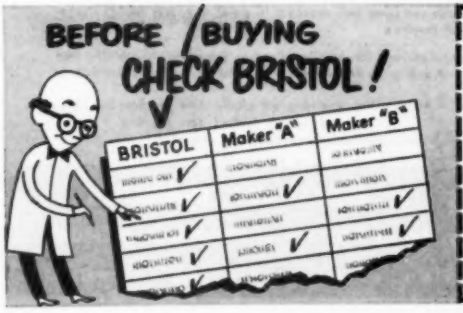

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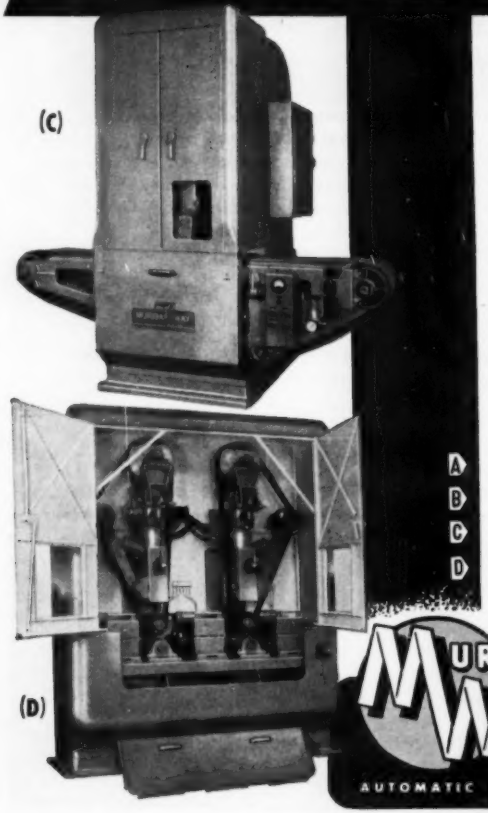

can automatically finish your job faster, better or cheaper regardless of size, shape or material.

Murray-Way, "engineered-to-the-job", Micro-Polish equipment is now being used the country over in every type of application, on every conceivable kind of material.

Micro-Polish is an amazingly versatile and consistently successful automatic polishing method useful on any job from the prepolishing of low grade steel sheet, to meet high quality job specifications, to the production sharpening and polishing of pruning tools.

Micro-Polish can precision finish any size, shape or length of sheet, strip or blanked stock in ferrous or non-ferrous metals, wood, fiber, plastic, rubber or leather, by wet or dry process.

The typical Micro-Polish equipment shown here demonstrates how Murray-Way engineers have adapted the process to individual job requirements.

A. A Micro-Polish giant used in reclamation grinding of steel strip.

B. One of our smaller units used in polishing narrow bi-metal stock.

C. A versatile unit using belt conveyor to polish a variety of flat stampings and forgings.

D. A space saver unit for polishing flat bar stock. Two heads and two grades of belt grain accomplish the complete job without rehandling.

Murray-Way engineers will gladly show you how this time and cost saving method can improve your polishing operation.

MURRAY WAY THE MURRAY-WAY CORPORATION

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We're especially proud of our tool steels . . . because users rate them tops in the field. In fact, users think so highly of them, they've made Crucible the country's number one producer of these fine steels.

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TOOL STEELS

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How much heat from a "heat" of Chromel?

You've seen molten metal before . . . but chances are you've never seen a "heat" that's more closely controlled as to composition and quality than the one you see above. For this is a heat of Hoskins Chromel . . . the *original* nickel-chromium alloy that *first* made electrical heating practical. Into it go precise amounts of the purest raw materials obtainable . . . mixed, melted, and poured in exactly timed cycles.

Heating elements made of Hoskins Chromel give long life service in industrial electric furnaces, home appliances.

Spark plugs equipped with Hoskins electrode alloys give long dependable service wherever they're used.

Hoskins Chromel-Alumel thermocouple alloys accurately register exhaust temperatures of jet aircraft engines.

And from it, ultimately, will come approximately 1200 pounds of fine finished material . . . smooth, bright, durable wire or ribbon produced to a specified resistivity for long, dependable service as heating elements or cold resistors in countless different electrical devices.

Chromel, however, is only one of many specialized, quality-controlled alloys developed and produced by Hoskins. Others include: Alloy 502 . . . used throughout industry for a wide range of heat resistant mechanical applications. Spark plug electrode alloys . . . which have become universally accepted standards of quality and durability. Alloy 717 . . . used in facing engine valves for longer life and improved service. And, of course, there are Hoskins Chromel-Alumel thermocouple alloys for industrial furnaces and jet engines . . . unconditionally guaranteed to register true temperature-e.m.f. values within close specified limits.

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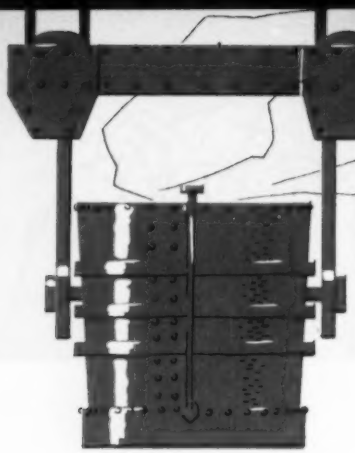


You Cut Down Interruptions In Your Metal-Melting Operations

When Norton SPECIAL Refractories are ENGINEERED for You

You never regain the production you lose when you interrupt your metal-melting operations to patch or repair your furnace linings.

So, it pays you to keep your interruptions few and far between. You can do it *only* with a refractory cement that fits your requirements exactly.

That's where Norton Refractory Research makes things easy for you. Tackling all kinds of high-temperature problems — complicated by chemical, electrical and physical variables — and coming up with special refractories to solve them has kept Norton Research busy for over 40 years. And you, too, can benefit from the findings of this research.

Whatever your problem, you can be sure that Norton Refractory Research has already licked it for somebody else . . . or is already working on it.

That's because Norton Research works with so many different refractories and compositions: CRYSTOLON* silicon carbide, ALUNDUM* fused alumina, MAGNORITE* fused magnesia, and the sensational new refractory FUSED STABILIZED ZIRCONIA.

See how they have solved the problems of other foundries . . . and check whether you can get similar results.

NORTON REFRACTORIES FOR HIGH FREQUENCY FURNACES

Chances are you, too, can melt more steel per lining by using Norton MAGNORITE cements. This applies to a wide variety of melts ranging from straight steel to heat-resistant compositions.

These cements have been developed specifically to be dry rammed and will withstand temperatures up to 3250 F.

They are designed to have a slight expansion upon maturing in order to eliminate any possibility of shrinkage cracks which might lead to furnace failure.

For smaller furnaces, you can get MAGNORITE crucibles in compositions that match your needs.

For melting platinum and its alloys, you can't beat Norton FUSED STABILIZED ZIRCONIA crucibles. They are not wetted by the metal. So, you can recover 100% of the melt without destroying your crucibles. You can also use the same crucible for different alloys without contamination.

NORTON REFRACTORIES FOR INDIRECT ARC FURNACES

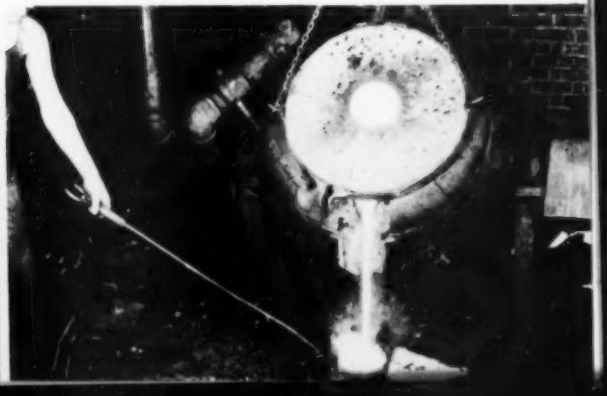
More and more foundries report excellent results with Norton ALUNDUM and MAGNORITE crocks, covers, and cements. These products are, of course, made to meet individual requirements. So, send along your specifications and see what our Research Department recommends . . . and why.

NORTON REFRACTORIES FOR LOW FREQUENCY FURNACES

Here, Norton Research has the same choice of two result-proved refractories: ALUNDUM and MAGNORITE cements. Tell us what metals you're melting: such refractory alloys as cupro-nickel and nickel silver; high copper alloys and Al, Te and Si bronzes. The one Norton ALUNDUM or MAGNORITE cement will be selected that will give you the longest lining life . . . a product with the high rammed density that resists metal penetration, erosion, and chemical attack.

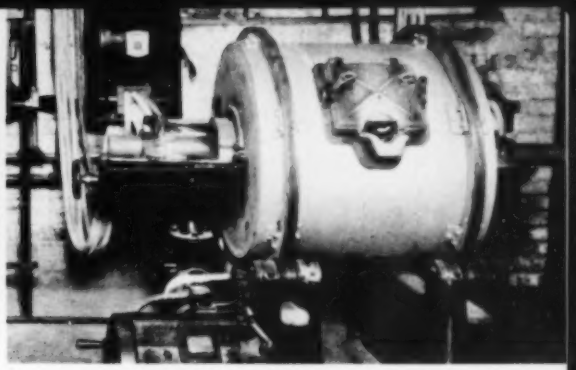
REMEMBER . . . ALL NORTON SPECIAL REFRACTORIES DESCRIBED HERE CAN BE ENGINEERED TO FIT YOUR EXACT REQUIREMENTS

THIS LOW FREQUENCY INDUCTION FURNACE has a special Norton MAGNORITE refractory cement lining which gives such a high rammed density that it resists metal penetration and erosion longer.



THIS TILTING CRUCIBLE FURNACE has a pre-fired CRYSTOLON cover and lining of a Norton CRYSTOLON refractory cement which were engineered to fit this firm's individual requirements

THIS HIGH FREQUENCY INDUCTION FURNACE is lined with a Norton MAGNORITE cement designed specifically to be dry rammed and to withstand temperatures up to 3250 F.



THIS INDIRECT ARC FURNACE owes much of its high output to its lining, made of a custom-engineered Norton refractories cement.

ALUNDUM CEMENTS STAND UP

In desulphurizing ladles, which involve addition of sodium carbonate, Norton ALUNDUM cements have proved successful. One report from a gray iron foundry, using a 1500 pound "U" type ladle, shows an ALUNDUM cement lasting two to four times longer than any other refractory month in and month out.

In steel ladles, too, ALUNDUM cement is equally successful. One plant, using it in a 1000 pound teapot ladle to handle stainless steel, stepped up the number of heats from 47 to 103.

Aren't results like these worth investigating?

CRYSTOLON SLAG HOLE BLOCKS OUTPERFORM FIRE CLAY

In back-slagging cupolas, Norton CRYSTOLON slag hole blocks have a great record of performance. Users report that those dense blocks hold their hole size anywhere from 8 to 30 hours . . . resist slag action 5 to 15 times longer than fire clay . . . show little or no signs of softening, spalling or cracking at temperatures as high as 3050 F.

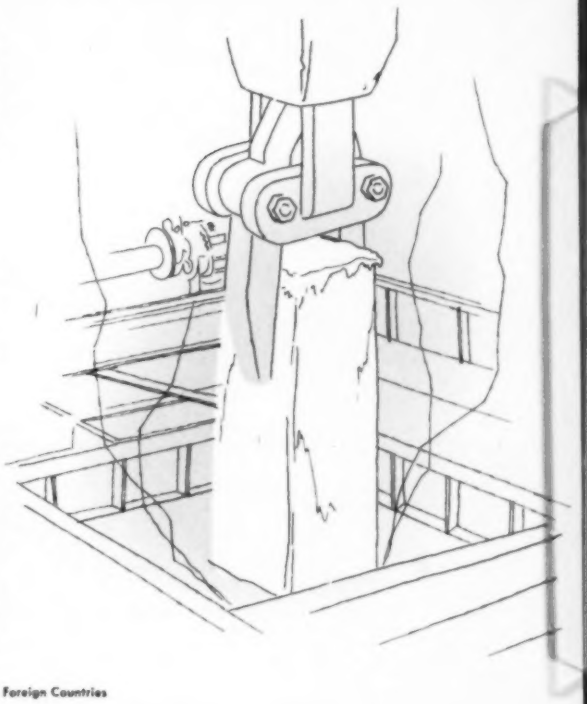
Why not compare their performance with whatever you are now using?

NORTON RESEARCH HELPS IMPROVE HEAT-TREATING AND SINTERING FURNACES

You, too, can operate at higher temperatures and lower costs . . . thanks to the wide variety of Norton refractory products, engineered to fit heat-treating and sintering requirements.

Look into ALUNDUM and CRYSTOLON hearth plates, pier brick, burner blocks, muffles, muffle plates, skid rails, recuperator tubes, burner-tunnel and embedding cements. You'll find that they combine high refractoriness, excellent thermal conductivity and stubborn resistance to spalling, corrosion, and erosion.

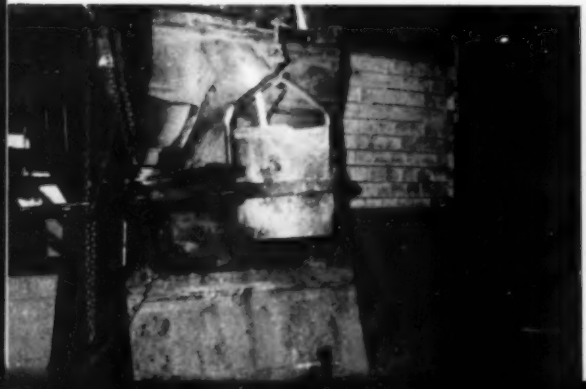
NOTE: In regards to thermal conductivity, make a note of this. Tests by independent laboratories using standard ASTM test methods prove that Norton CRYSTOLON silicon carbide brick, hearth plates, etc. equal or exceed in thermal conductivity any other silicon carbide shapes in use today.



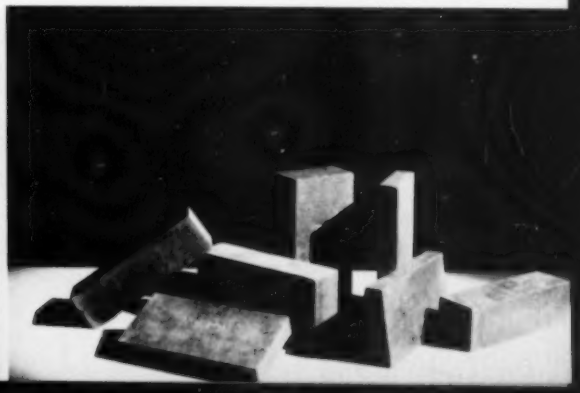
LET'S TALK IT OVER.

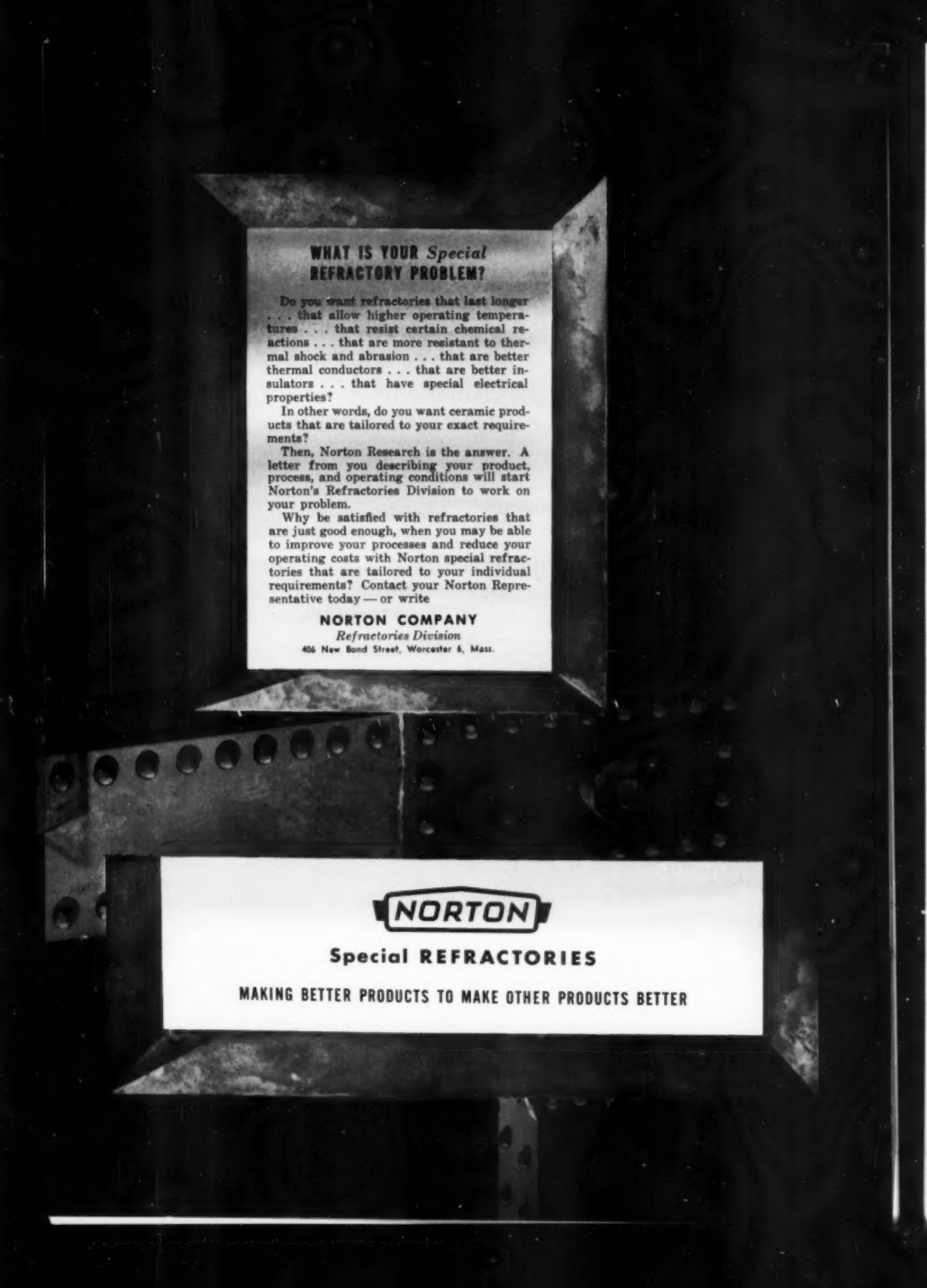
*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

THIS DESULPHURIZING LADLE was lined with a special Norton ALUNDUM refractory cement which outlasts other refractories as much as four to one.



THESE NORTON CRYSTOLON SHAPES, according to independently conducted ASTM tests, equal or surpass in thermal conductivity any other silicon carbide shapes in use today.

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Do you want refractories that last longer . . . that allow higher operating temperatures . . . that resist certain chemical reactions . . . that are more resistant to thermal shock and abrasion . . . that are better thermal conductors . . . that are better insulators . . . that have special electrical properties?
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Then, Norton Research is the answer. A letter from you describing your product, process, and operating conditions will start Norton's Refractories Division to work on your problem.
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Metal Progress

Vol. 62, No. 1 • July, 1952

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The Effect of Iron on the Corrosion Resistance of Copper-Nickel Alloys .. 174
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Mold Blowing Reaction 176
By V. Kondic, G. Martin and K. Bromage, *Metallurgia*, Vol. 45, March 1952, p. 127.

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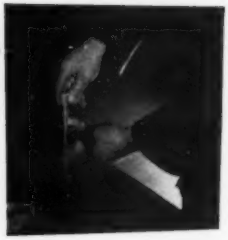

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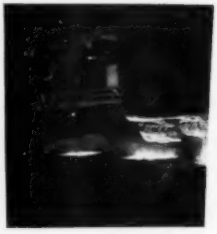

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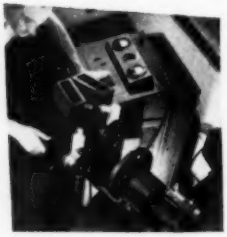

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Ion Exchange—a New Technique for Metallurgists

By **Bernard Ostrof**, Technical Staff, Rohm and Haas Co., Philadelphia,
and **Ernest E. Thum**, Editor, Metal Progress

ION EXCHANGE is a chemist's term which represents methods and techniques highly perfected in the last decade. As a process, it is not new. In a most simple form it was used by the ancient Greeks when they passed salty and foul water through beds of crushed rock and thus rendered it potable. A century ago two English agricultural chemists, H. S. Thompson and J. T. Way, found that if certain soils were soaked in solutions of ammonium salts, the liquids gradually lost ammonia and acquired calcium. They concluded that the ammonia ions originally in solution interchanged with the calcium in the solid minerals.

By 1875, it had been discovered that the family of minerals called zeolites were much more active than other minerals in this respect, zeolites being complex hydrous silicates of the alkali and alkaline earth metals. By the turn of the century natural zeolites came into use in water softening equipment, and by the middle 1930's artificial zeolites for this purpose were being manufactured. However, the extraordinary expansion in uses and possibilities of the general method of ion exchange has occurred only in the last decade, following the discovery of means to synthesize resins having ion exchange properties.

Applications of interest to metallurgists are the purification of electroplating solutions; the recovery of valuable metals or acids from spent pickling solutions and other wastes;* the separation of the rare earths which are almost identical chemically; similarly, the purification of zirconium from its congener hafnium. But before these processes can be described intelligently, it is necessary to say something about synthetic ion exchange resins and how they work.

An illuminating experiment has been described by Breton and Schlechten in *Journal of Metals* (American Institute of Mining and Metallurgical Engineers), July 1951, p. 517. A vertical glass tube, about 1 in. diameter and 40 in. long, was filled halfway with bead-like particles of a resin known as "Amberlite IRC-50" in its sodium form. Down through this tube seeped a solution of copper and zinc sulphates. A copper color quickly appeared at the top of the column of resin and slowly widened. The effluent from the bottom of the tube had neither copper nor zinc, but did carry an equivalent mol concentration of sodium. Evidently the sodium ion in the resin had exchanged places with the copper and zinc; furthermore, the reaction was complete.

After some 16 liters of solution had passed, the effluent showed a little zinc, but no copper. After four more liters had passed, the effluent was still free of copper, but had as much zinc in it as the solution entering the tube. At that time, the copper color on the beads of resin had extended about halfway from top to bottom. Evidently, this particular resin replaced copper with sodium more rapidly than it extracted the zinc.

The experiment continued; more zinc-copper sulphate solution entered the top of the tube; the copper color extended further and further down; the effluent contained no copper, but carried the original concentration of zinc and mol equivalent of the missing copper in sodium; by the time a total of 32 liters of solution had passed, copper appeared in the effluent and rapidly gained in proportion with further passage of solution.

Obviously, the preference of this particular resin for copper was so strong that complete separation of copper and zinc occurred during the last half of the run. The resin became "saturated" with the two metals rather rapidly, however.

Lastly, this resin was regenerated by a countercurrent solution of common salt

*Investigators for the allied armies found, for example, that during the war some 17 tons per day of copper, which would otherwise be lost, was recovered in Germany from rayon mill wastes with the aid of ion exchange resins.

which puts sodium back into the organic molecule and takes the copper and zinc away in solution as chlorides.

This experiment illustrates a method which is useful in making clean separations otherwise extremely difficult. What, really, has happened? Why should a sodium ion, for example, change places with a copper ion when both of them have the same electrical charge, both are "cations" with one missing electron, hence having unit positive electrical charge?

Questions such as these have been argued at length, and no less than three plausible general theories have been advanced which our present purpose does not require us to discuss. At any rate, the action is not physical — a mere matter of adsorption. This is proven by the fact that crystals of a zeolite react in a water softener in proportion to their mass, and not in proportion to their surface; sodium zeolite (hydrous sodium silicate), for example, may be *completely* transformed to a calcium zeolite. It follows that the crystalline structure must be "open" enough so the sodium ions can diffuse to the surface and the calcium ions can diffuse into the crystal in what might be regarded as a "grand right and left". While the synthetic resin exchangers lack crystallinity, the reaction also permeates the whole gel structure. Ion exchange may, therefore, be defined as the reversible interchange of ionized atoms or radicals between a solution and a solid in an action which results in no change in the physical structure of the solid.

The synthetic ion exchangers, as we know them today, derive from the studies made by B. A. Adams and E. L. Holmes in the middle 1930's. The resinous cation exchangers which they prepared were notably superior to earlier materials from the standpoint of stability and capacity, and consequently improved the economics of possible industrial uses. Perhaps more important were the *anion* exchangers prepared by these men, for they extended the domain of ion exchange into hitherto unexplored realms.

Synthetic ion exchange resins are polymers (multiple molecules) of high molecular weight, to which is attached an ion or which contain ionic groups as part of their structure. Those designated as cation exchange resins are polymers made up of groups of phenolic acid molecules (C_6H_5OH), sulfonic acid (SO_3H), carboxylic acid (CO_2H), or phosphonic acid $PO(OH)_2$, surrounded by cations. Anion exchange resins contain nitrogenous groups, together with an equivalent number of anions such as sulphate, chloride, and hydroxyl. Typical units are diagrammed in Fig. 1.

When the anions or cations surrounding the fundamental structure are replaced either partially or completely by an equivalent number of similarly charged ions, ion exchange has occurred. This exchange may be brought about by passing the solution to be treated through a column of the resin as described in the copper-zinc experiment at the outset, or by mixing resin and solution in batches. When the sodium form of a cation exchanger is used, the resin is said to be "operating in the sodium cycle" — when the hydrogen form is used, in the hydrogen cycle, and so forth. Regeneration of the resin — that is, conditioning it for reuse after its original exchange capacity is exhausted — is accomplished by treating the resin with another solution containing the ions attached to the resin initially. Sodium chloride is a common regenerant for cation exchangers, converting these back to the sodium form.

If the resin be indicated by the symbol Rz, the removal of a cation from a solution, say copper, may be represented by the equation

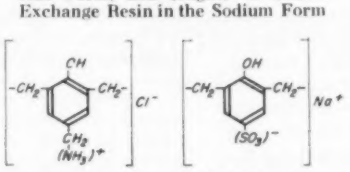
$$2RzNa + Cu^{++} \rightarrow Rz_2Cu + 2Na^{+}$$

Similarly, the removal of a chloride ion by interchange with hydroxyl:

$$Rz(OH) + Cl^{-} \rightarrow RzCl + (OH)^{-}$$

Cation exchangers and anion exchangers are both made in strongly ionized and in weakly ionized modifications. It is probably unnecessary in an article for a metallurgical magazine to say anything about the chemical manufacturing processes. Likewise, the metallurgist with a problem to solve would do well to consult with a competent chemical engineer concerning the concentration and pH of the solution to be treated, the kind of resin

Fig. 1 — Typical Units (Left) of Anion Exchange Resin in the Chloride Form, and (Right) of Cation Exchange Resin in the Sodium Form



Anion Unit Cation Unit

and its particle size, and the arrangement of equipment (whether for continuous or for intermittent operation). In many proposed applications some preliminary laboratory investigations will be necessary. Labor-saving devices may also involve some more or less elaborate instrumentation.

Usually most of the solutions to be treated are dilute (for example, hard water). This is no obstacle to the process but will probably affect the size of the towers, tanks and piping arrangements. In general, the higher the concentration of a given ion in the influent, the greater the leakage of that ion into the effluent.

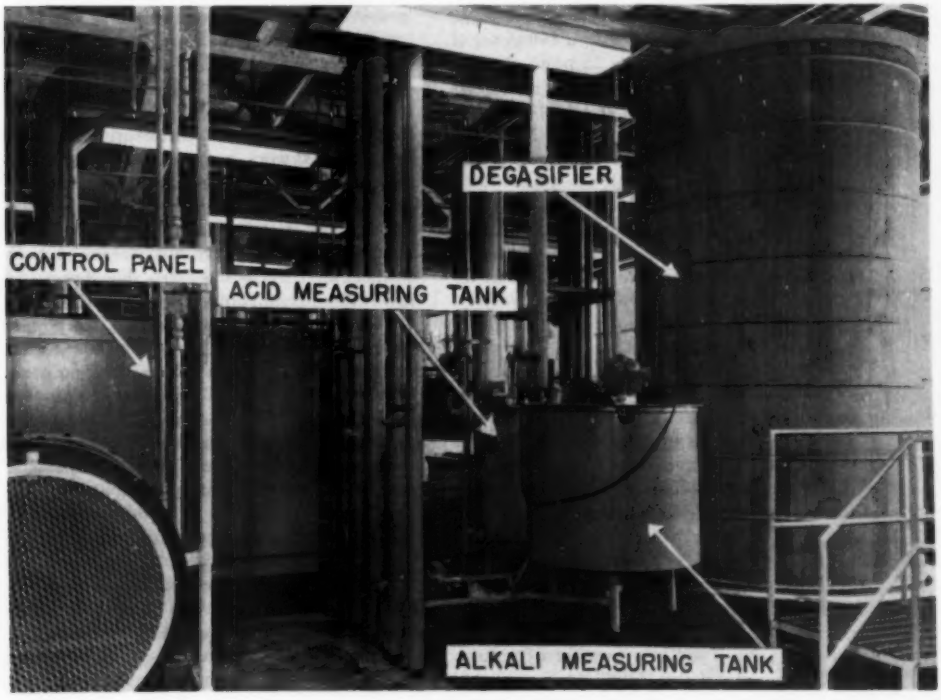
Water Purification — First a word about the important topic of water purification or demineralization — since it is not only the commonest and the most ancient of the applications, but because it has many uses for the plating superintendent or the metallurgist who may be harassed with scale deposit from hard water in his water-cooled furnace parts. For example, the editor of *Metal Progress*, in his "Critical Point" (January 1951), describing the new Indianapolis plant of Western Electric Co., might have said that deionized water is supplied to the electroplating department (a model in many ways). The raw water supply is pretty bad; treated water prevents the precipitation of calcium carbonate in the tank and wash solutions, is far cheaper than distilled water — its only equal — and prevents many difficulties in the automatic control of uniformly high-quality plating.

The simplest form uses only the softening step, wherein the calcium (or "hard") ions from the lime or gypsum in solution in the water are replaced by the sodium (or "soft") ions of the resin. A resin like Amberlite IR-120 will also capture magnesium and other metals in the water. The principal reaction may be written as follows:

$$2\,RzNa + Ca(HCO_3)_2 \rightarrow RzCa + 2\,NaCO_3 + H_2CO_3$$

The simplest way to perform continuously this essential step is in equipment dia-

Fig. 2 — Equipment for Deionizing Hard Indianapolis Water at Western Electric Co. Pure water is a boon to electroplaters



grammed in Fig. 3, permitting what is called a "fixed-bed operating cycle". Four steps are involved:

1. Reaction between resin and hard water as it passes downward in the left-hand column in Fig. 1.

2. Backwash of the companion right-hand column by a current of raw water to remove dirt.

3. Regeneration of the exhausted bed (right column) by salt solution.

4. Rinsing the regenerated bed free of regenerant.

Step No. 4 must be completed before step No. 1 exhausts the left bed of its available sodium ions. At the proper moment valves are reversed, the newly regenerated bed is put "on stream" and the exhausted bed is ready for steps No. 2, 3 and 4.

The above simple equipment represents water "softening" such as is valuable for domestic purposes. However, a three-stage process is suitable for real purification to the equivalent of water or better (1 part per million of dissolved solids). A typical water supply might have 150 parts per million of calcium, 50 ppm. of magnesium, 10 ppm. of potassium plus sodium, 150 ppm. of H_2CO_3, 40 ppm. of SO_4 and 25 ppm. of Cl.

The problem generally, then, is to pass such water through a column of strongly acidic cation exchanger such as Amberlite IR-120 in the hydrogen form, which produces an effluent with acidic reaction. Next, the CO_2 from break-up of H_2CO_3 is eliminated by aeration in spray towers. Finally, this half-purified water is passed through a column of strongly basic anion exchanger like Amberlite IRA-400 in the hydroxyl form, which removes the acids in the water by means of this interchange:

$$RzOH + HCl \rightarrow RzCl + H_2O$$

Application in Chromium Plating — As mentioned above, use of demineralized water is a boon to electroplating solutions. It is also very useful in recovering valuable metals from process solutions which might otherwise be lost, or in regenerating contaminated solutions.

For example, early in 1950, R. L. Costa published in *Industrial and Engineering Chemistry* a method for purifying chromic acid by an ion exchange process. This is now being employed at a number of plating plants throughout the United States.

As is generally known, plating baths become contaminated with foreign cations — primarily iron, aluminum, manganese, and copper. Costa purified these contaminated liquors simply by passing the chromic acid solution through a bed of strongly acidic cation exchanger (Amberlite IR-120). Results obtained in typical experiments are as follows, where figures represent grams per liter of solution:

	Influent	Effluent
CrO_3	72.6	69.4
Al_2O_3	7.74	1.52
Cr_2O_3	0.9	0.3
CuO	0.19	0.04
MnO	0.006	0.001
pH	0.65	0.34

Since the concentration of chromic acid plating baths is usually high, dilution is required before treatment, and it is then necessary to concentrate the purified solution in glass-lined evaporators.

Treatment of Rinse Waters — In decorative chromium plating the dragout may be so great that the bath itself is but slightly contaminated, while metals accumulate in the rinse. Contamination is allowed to build up in such tanks until a significant concentration is attained, whereupon it may be purified as indicated above.

There are a number of reasons for attempting to recover chromium from work solutions. It is scarce, expensive, and is toxic to aquatic life. Unfortunately, some of the early work required such costly regenerants that further study and application of this process were halted.

Recently, a process for recovering chromate on a strongly basic resin such as Amberlite IRA-410 has been developed. In favorable circumstances, this absorbs about 13 kg. (calculated as calcium carbonate equivalent) per cu.ft., and can be regenerated by 10 to 20 lb. of caustic per cu.ft. Passage of the spent regenerant from the Amberlite IRA-410 bed through a strongly acidic cation exchanger may cheaply recover the chromate as concentrated chromic acid for recycling to the plating bath.

RECOVERY OF METAL FROM PICKLING LIQUORS

Iron — Nowhere in industry are the volumes of waste solutions so large or the total quantities of lost metal values so great as in the steel industry. About one third of the 80,000,000 tons of finished steel shipped

from our primary producers requires to be cleaned of mill scale near the end of the rolling process, and much of the steel shipped as "hot rolled" is later pickled in fabricating plants. Richard D. Hoak of Mellon Institute estimates that some 600,000,000 gallons of spent liquor is produced annually, containing about 2% of free sulphuric acid and around 16% of ferrous sulphate. This means that 150,000 *tons* of iron is lost annually in pickle waste, from the steel plants alone, and double that tonnage of sulphuric acid. Aside from this waste in natural resources, the problem of safe disposal is a very serious one. A large number of workers have studied the problem and eighty-odd processes have been proposed for recovery of the values. As of today, however, almost all of the spent liquor is thrown away, either without treatment or after neutralization with soda ash, slaked lime, or pulverized limestone.

While the favorite acid for pickling common steel is 6% sulphuric, with or without organic inhibitors, hydrochloric and other acids are used frequently for cleaning alloy steels, especially those containing chromium, and the stainless family. Waste solutions, therefore, contain valuable chromium as well as iron.

If a solution of HCl containing iron is concentrated by evaporation to 6*N*, normally cationic iron is bound with chloride ions in anionic complexes such as $FeCl_4^-$ or $FeCl_5^=$. By employing an anion exchanger in the chloride form, this complex is quantitatively removed and the acid recovered. Regeneration is simple. Water is passed through the resin bed, converting complex iron anions to ferric chloride and hydrochloric acid.

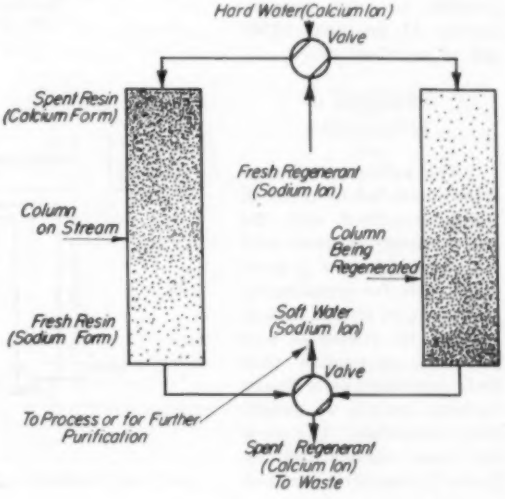
This *selective* removal of anionic complexes in the presence of competing ions has many present and potential applications. Metals of high coordination number forming complexes similar to those of iron often may be separated by ion exchange. Similarly, certain high-molecular weight or polyvalent anions may be removed. Among those metals which may be so isolated are chromium, manganese and copper.

Another important pickling reagent — especially in recent years — is phosphoric acid. Dilute solutions (15 to 50%) not only remove oxide but build up on the cleaned surface a coating that is a good carrier of lubricant for cold working operations, or is rust preventive and an excellent base for paint or finished parts. However, high costs have restricted its use. To reduce acid costs, Caterpillar Tractor Co. has installed an automatic pickling line at the plant in Peoria, Ill., sketched in Fig. 4, which continuously purifies the acid. As the pickling solution trickles down through the bed of resin in the regenerating tank (Fig. 5), it gives up its iron cations, receiving in return hydrogen. Periodically, on night shift when the line is down, the resin is washed clean of pickling solution and regenerated by 30% sulphuric acid; iron sulphate drains down into the neutralizing tank and is eliminated from the system. When the regenerating tank is washed clear of the sulphuric acid, it is again ready for the pickling line.

Copper and Zinc — Among the metallic wastes which have received considerable attention in recent years is the pickling waste from the brass mills. Some 1500 tons of copper and 1100 tons of zinc were lost in brass mill wastes during a single year in Connecticut alone.

The initial work toward saving this metal through ion exchange was apparently performed abroad and published in 1936. More recent work of Bliss, McGarvey, and

Fig. 3 — Sketch of Fixed-Bed Operating Cycle Where Left-Hand Column Is on Stream and Right-Hand Column Is Being Regenerated (Stanford Research Institute). Degree of shading indicates the amount and location of calcium in the resin column at about midcycle



their associates demonstrated that the new high-capacity cation exchange resins are applicable to the recovery of zinc, copper and chromium from pickling baths. Figure 6 is a flow sheet.

Either the sodium or hydrogen cycle may be used, although economics favors the hydrogen cycle, wherein spent acid is recovered for pickle make-up. A major factor influencing capacity for zinc and copper, particularly important where the copper concentration in the rinse water is rather low, is the relative amount of calcium and magnesium hardness in the raw water supply — a matter under absolute control, as indicated in the opening portion of this paper.

Where elimination of toxic metals is of primary concern, the sodium cycle offers the following advantages: *(a)* less sensitivity to total hardness in rinse water; *(b)* greater capacity; *(c)* higher concentration of toxic materials in the regenerant; *(d)* decreased acidity; and *(e)* more thorough removal of trivalent chromium. Copper, zinc and chromium may be precipitated from the waste sodium chloride regenerant by sodium carbonate, and either refined in a small electrolytic tank or sent to smelters for recovery.

The economics of this recovery process is encouraging. For example, with an influent containing 640 ppm. copper (or copper plus zinc calculated as copper), and basing cost of regenerant and labor on current values in the Naugatuck Valley, it is possible to save approximately $1 on each 50,000 gal. of solution.

SEPARATION OF RARE EARTHS

The brilliant investigations conducted by research teams associated with the atomic energy program used ion exchange resins as powerful tools for quantitative separation of ions so closely related in chemical and physical properties that their separation by ordinary chemical means is practically impossible. The work has been summarized by Frank H. Spedding (head of the Ames, Iowa, Laboratory of the U. S. Atomic Energy Commission) in *Discussions of the Faraday Society*, 1949.

This research work led from the early discovery that some of the rare earths are formed as fission fragments of uranium. Since such fission products may slow down the chain reaction in the uranium pile by absorbing neutrons, it was necessary to know the captive "cross sections" of all the elements in question, as well as their chemical properties so they could be removed as necessary from partly spent uranium. Although this work is too extensive to consider in any detail, the accomplishments resulting from the ion exchange operations may be outlined as follows:

1. Large-scale separation of the rare earths, eliminating the tedious fractional crystallization techniques previously employed. Older techniques required as many as 20,000 operations.

2. Elucidation of fundamental physicochemical principles governing adsorption by ion exchange.

3. Isolation and identification of over 15 different radioactive isotopes found as byproducts of atomic fission.

4. First conclusive evidence of the existence of element 61, variously called promethium and illinium, by isolation and identification of an isotope possessing the required properties.

The separation of ions, in this tech-

Fig. 4 — Diagram of New Phosphoric Acid Pickling System at Caterpillar's Peoria Plant (Courtesy Lead Industries Assoc.)

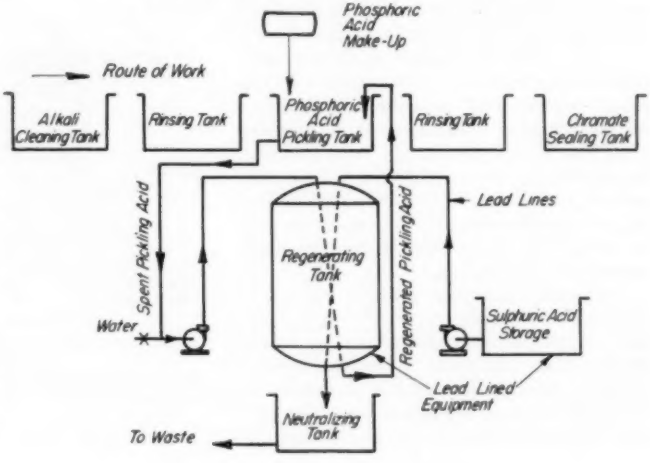


Fig. 5 — Regenerative Equipment in Phosphoric Acid Pickling Line at Caterpillar Tractor Co.'s Peoria Plant. Sulphuric acid is stored in the tank in front of operator; regenerating tank for phosphoric acid pickling solution is tall tower at left

Experiments at Ames Laboratory

nique, depends on the differences in the "affinity" of the resin for the various ions in the entering solution. The separation method is a batch process. A similar operation has been briefly described at the beginning of this article in the experiment with mixed copper and zinc sulphates. The following notes have been paraphrased from Dr. Spedding's article.

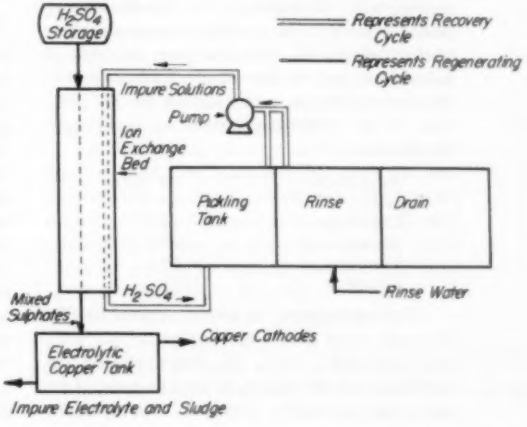
A 100-g. sample of "neodymium carbonate", a byproduct of the refining of a cerium ore, and really containing about 9% samarium oxide, 75% neodymium oxide, and 16% praseodymium oxide (elements 62, 60 and 59, respectively), was dissolved as chloride, diluted to about 5% concentration, and placed in a tall glass tube 4 in. diameter on top of an 8-ft. bed of Amberlite IR-100 that has been previously conditioned with hydrochloric acid.

The rare earths are quickly removed from the solution by the resin, and would remain at the top of the column were it not that the chloride solution is followed by a 0.5% citrate solution of pH 3.9. Only after some 440 liters of liquid had trickled through the valve at the bottom of the column did the first metal appear. Spectroscopic analysis showed it to be samarium, the heaviest of the metals, and it was free of both neodymium and praseodymium.

As elution continued, periodic analyses of the effluent were made, and results plotted as in Fig. 7. It is obvious that it is only necessary to watch the analysis of the exit stream and divert it into different channels at appropriate times. In the run represented by Fig. 7, five fractions could be cut, pure Sm, Nd and Pr compounds (which were sought) and two mixtures which can be added to the raw material in the next batch to be treated. Dr. Spedding comments on this operation as follows:

"Since, at best, any single chemical operation gives only a slight enrichment of one adjacent rare earth over another, it is obvious that to separate successfully the rare earths into their pure fractions it will be necessary to have a process which automatically repeats the same operation many times. These conditions can be fulfilled in an ion-exchange column. When the mixed rare earth chlorides were

Fig. 6 — Simplified Diagram of Cycle for Recovering Copper From Brass Mill Pickling Wastes



poured in the top of the column, the width of the adsorbed band of rare earths in the column occupied only a fraction of the top.

"While the rare earth ions are tightly adsorbed on the Amberlite in the low-pH range, at the pH where the following citric acid solution is flowing through the column an equilibrium is set up between the Amberlite-earth complex and the citrate complex. The equilibrium constants differ slightly for the different rare earths and this causes the heavier rare earths to move down the column more rapidly than the lighter rare earths. Since the shifting back and forth between the resin and the complex ion must occur thousands of times as the rare earths move down the column, this ultimately results in the separation of the earths which come out at the bottom."

This separation of the earths into bands as they move downward has been given the name of "chromatographic separation"—quite *apropos* when copper or some colored ion is included. In controlling the process, it is also handy to mix with the raw material traces of the artificially radioactive elements (for example, Sm, Nd and Pr in the run shown in Fig. 7). Frequently, their radiation is sufficiently different that the various elements can be "seen" by suitable counters.

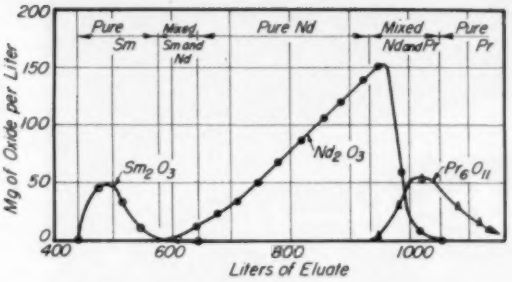


Fig. 7 — History of a Pilot Plant Run Wherein Three Adjacent Rare Earths Were Cleanly Separated (Spedding)

PURIFICATION OF ZIRCONIUM

Zirconium (element 40) is a metal of considerable importance to atomic energy power reactors, since it has a good combination of chemical, physical and mechanical properties, and is also fairly transparent to thermal neutrons, as is shown by its position in the following list of heat resistant elements:

Zirconium	0.4 barns
Iron	2.4
Chromium	2.9
Nickel	4.5
Titanium	5.8
Tungsten	18.0

Unfortunately, however, element 72, hafnium (just below zirconium in the periodic sequence) with the large absorption coefficient of 100 barns, is always present in zirconium minerals, and the two elements are so like in their chemical nature that even specially refined commercial zirconium contains too much objectionable hafnium.

Again, ion exchange comes to the rescue. In full-scale equipment quite similar to that already mentioned, zirconium is purified on a tonnage scale. (Further separation of isotope Zr^{90}, with neutron cross section of 0.12 barn and comprising half of the natural metal, could be effected from the hafnium-free metal by the electromagnetic or diffusion processes used for uranium if requirements warranted.) Among the possibilities for hafnium separation are columns filled with Amberlite IRA-400 in the chloride form. Zirconium (and hafnium) hydroxide is dissolved in a slight excess of HF, and a radioactive tracer element added (Zr^{95}). Sharp cutoff points appear in the effluent, the heavier hafnium coming through well ahead of the zirconium.

CONCLUSION

It is hoped that the engineer who has read this far is persuaded that ion exchange is a process which is of great importance to many metallurgical operations, ranging from purification of radioactive and even artificial metals to such humdrum matters as washing finished parts. A most important thing to remember is that values can be recovered from *very* dilute solutions without expensive evaporation.

Only the simplest of apparatus has been mentioned. Obviously, there are possibilities of designing a completely continuous and practically automatic operation — a matter involving intricate sampling and control equipment more in the province of the chemical engineer than the metallurgist.

Distortion and Service Tests of Carburized Gears Made of Boron Steels*

By **S. L. Widrig**, Chief Metallurgical Engineer, and **Wilson T. Groves**, Metallurgical Engineer
Spicer Mfg., Division of Dana Corp., Toledo, Ohio

A TEST PROGRAM for determining optimum heat treating procedures on automotive transmissions made from boron carburizing steels was described in the June issue of *Metal Progress*. Parts made from 80B00 and 8600 steels were processed simultaneously and their behaviors compared. The parts consisted of a 28-lb. countershaft, two gears of different cross section, experimental lots of pinions, ring gears and pinion mates, and universal joints.

In the heat treating procedure described, there was no significant difference in distortion between the pinions made from 8620 and 80B20 steel. This was not true for ring gears, however. The gears made from 80B20 had excessive bore shrinkage which is a general characteristic of boron steels. Tooth distortion was also excessive. Despite numerous changes in the quench dies and in the hydraulic pressure to the ram and bore expander, we could not make these parts successfully from this steel. Pinion mates also showed both excessive bore shrinkage and taper, and consequently we have abandoned the use of 80B00 steels for these parts.

Excessive bore shrinkage has also been troublesome in the transmission gears with splined bores. Bore shrinkage is often attributed to high core hardenability, and this probably does have some influence, since the 4320 steel used some years ago caused greater bore shrinkage than the 8620 subsequently used. However, the 80B17 and 20 are even worse than 4320, although their inherent hardenability is generally somewhat less, as shown in Fig. 2 (June *Metal Progress*, page 74). At Spicer we have started a rather extensive program to investigate this phenomenon using 4320, 8620, 8123, 80B17 and 94B17. Results will not be available for some months.

Press Quenching — On gears having involute spline bores, the "fit" between gear and shaft on which it slides is usually between the root diameter of the splined gear and the outside diameter of the splined shaft. The shaft is ground to size after hardening but there is no further sizing operation on the splined bore. Consequently its root diameter must be held closely during heat treatment, and a splined plug is inserted prior to quenching for this purpose. A quenching press is also sometimes used to keep the gear flat.

On one particular mainshaft gear quenched on a plug and in a press the bore size with 80B20 steel was 0.004 in. less than with 8620 processed similarly. We attempted to cure the matter with an oversize plug, only to find that it was almost impossible to push the plug out of the hardened gear, which then contracted too much anyway! The specified size was finally obtained by carburizing and slow cooling to room temperature, followed by reheating to 1525° F. and quenching in a press with the standard quench plug. The former cycle for this part was to carburize at 1700, cool to 1550° F. in the furnace and quench.

Although the reheat operation seems to be a temporary solution, it has production disadvantages and larger broaches will be purchased if we continue to use boron-treated steels for this type of gear. This is a rather expensive proposition, since it involves not only the cost of the broach but also the cost of new arbors and gages throughout the machine lines.

Although the gears made from boron-treated steel have considerable bore shrinkage during heat treatment, the pitch diameter measured over pins or balls is only slightly less than in the older steels. Also there is generally no significant difference in tooth form; no changes have been required in the cutting of green gears.

*The first installment of this article covering "Forgeability, Machinability and Hardenability of Boron Carburizing Steels" appeared in the June issue of *Metal Progress*, page 73.

Dynamometer Tests for Transmissions

Martempering — In several instances we changed from our conventional oil quench to a martempering operation in order to hold gear tooth taper and warp within allowable limits in gears made of 80B17. A sample lot of 12 gears shown at the right in Fig. 9, made from the 80B17 specified in Table II (June issue, p. 75), run in the usual manner (carburized at 1700° F., oil quenched from 1500° F. on tray in open tank), were all above the allowable limits of taper and warp. Three different test lots of 10 gears each of this same steel were carburized and martempered and all these gears were within the specified limits in this respect.

In establishing the green dimensions of shafts we usually allowed for a longitudinal expansion of slightly less than 0.001 in. per in. during carburizing and hardening of 8620, the actual amount varying somewhat with section size. The 28-lb. countershaft illustrated in the first installment (Fig. 4) grew approximately 0.018 in. in over-all length. The same shaft made from the 80B20 steel, however, actually shrank approximately 0.006 in. We have no explanation for this difference.

It would be expected that this lengthwise shrinkage would be accompanied by an increase in diameter. This has been found, but it is small and has caused no particular trouble. However, the width of the keyway has increased from 0.003 to 0.005 in. more than on the 8620 shafts, and corresponding changes had to be made in the green dimension. Keyways in the bores of 80B20 gears close in only slightly more than in 8620, despite the much greater bore shrinkage.

RESULTS OF FATIGUE TESTS

Table III shows results of dynamometer tests for transmissions built up from the alternative steels, the parts being cut with the same tools and processed in the same way. Failure always occurred in the first-speed mainshaft gear. For this limited number of tests, and for this particular gear, the 80B20 steel has somewhat better fatigue properties. The effect of varying radii on the calculated unit stress at the root of the teeth and the actual fatigue life is demonstrated by tests No. 1, 2 and 3.

We also ran some 20 fatigue tests on a special testing machine where a set of two identical gears is loaded to a predetermined

Table III — Dynamometer Tests on Heavy-Duty Automotive Transmissions
Input torque, 430 ft-lb., 1800 r.p.m.

Test and Steel	Unit Stress	Compressive Stress	Failure*		Tooth Dimension	
			Time	Cycles	Root Radius	Tooth Bearing
No. 1 — 8620	80,200	273,000	14.5 hr.	210,000	0.043	93%
No. 2 — 8620	68,000	277,000	33	512,000	0.068	90
No. 3 — 8620	65,792	271,000	43	642,700	0.068	94
No. 4 — 80B20	65,792	271,000	59	896,200	0.068	94
No. 5 — 80B20	65,792	271,000	54	795,700	0.068	94
No. 6 — 80B20	65,792	271,000	51	754,000	0.068	94

*All failures occurred in first-speed gear having 61 teeth, 17½° pitch angle, 6-7 pitch, 1.312 face width. Unit load: 5576 lb. per in. face. Dynamic load: 6250 lb. per in. face. Pitch line velocity: 664 ft. per min. Rotations per min.: 246.

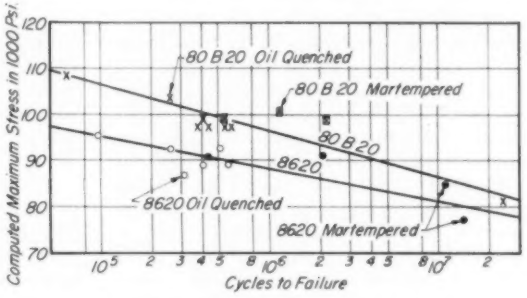


Fig. 7 — Endurance Tests on Pairs of Identical Carburized Gears Show Superiority of Gears Made of Steel 80B20 Over Steel 8620 and of Martempering Over Oil Quenching

value and run at 2200 r.p.m. to destruction. The gears were 10 pitch, 6-in. pitch diameter, tooth 1 in. wide, and weighed 7½ lb. The stresses at the root of the teeth were calculated, considering such variable factors as dynamic loads, tooth spacing error, lead error and stress concentration at the fillet. Results are shown in Fig. 7, wherein straight lines have been drawn to represent approximate S-N curves for the two steels. The curve for 80B20 lies definitely above the curve for 8620 — again indicating superior fatigue properties.

It is interesting to note that two sets of martempered gears made of both steels had much better life than similar gears quenched conventionally in oil. Although the former showed less distortion than the latter, this does not seem to be the sole explanation, since dimensional errors were taken into account in calculating the stresses. Also the two different quenching methods seemed to make very little difference in the hardness gradient across the case at the pitch line or root of the tooth of this relatively small gear, so hardness differences were not responsible.

It is well known that residual stresses have an important influence on fatigue, and

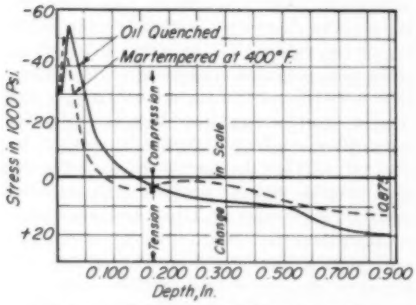


Fig. 8 — Residual Stresses (Longitudinal) in Carburized Bars of 8620, Heat Treated in Two Different Ways

the two quenching methods might produce an altogether different residual stress pattern. We knew of no method to determine such stresses, quantitatively, in gear teeth. We did, however, compare such stresses in cylindrical sections, feeling that any *differences* of residual stresses might also exist *relatively* in gears.

We arbitrarily selected two 7-in. bars of the same heat of 8620 steel and machined them to 1¾ in. diameter. The bars were carburized simultaneously 0.050 in. deep, cooled to room temperature, reheated to 1550° F. in a neutral salt bath, and quenched, one in 130° F. oil and one in 400° F. salt. To minimize any end-quenching effect, we then discarded 1¾ in. from each end. A ¼-in. disk was cut from one end of each remaining central portion and was used to determine the hardness gradient across the section.

The remainder of the hardened cylinders were lightly polished and four SR-4 strain gages were attached. Two of them, 180° apart, were mounted longitudinally, and the other two, also 180° apart, mounted circumferentially. Axial holes progressively larger in diameter were then machined and the surface movements measured by the strain gages. After the soft core had been practically removed, the strain gages were moved to the inside surface and the case then ground to successively greater depths.

Movements recorded by the strain gages were then plotted as a function of cross-sectional area removed, and residual longitudinal stresses calculated by Sachs' method.* (See Fig. 8.) There is no material difference except that the compressive stresses in the oil quenched bar reach a slightly higher maximum and extend somewhat deeper than in the martempered bar, probably due to a slightly greater depth of hardening. (Circumferential stresses were also plotted and showed the same general trend; radial stresses are small and relatively insignificant.)

On the basis of these tests we must conclude that the increased fatigue properties of martempered gears are *not* due to a more favorable pattern of residual stresses. Possibly martempered gears do permit a better distribution of stresses or exhibit a decreased notch sensitivity.

RESISTANCE TO CHIPPING

Another requirement of transmission gears is resistance to chipping during shifting. We have a machine in our laboratory to determine this property, consisting of a transmission mounted on a test jack. The mainshaft is driven by a variable speed

*"Internal Stresses in Piston Rods of a Large Diesel Engine Ocean Liner", by George Sachs, *Transactions*, 1939, p. 821.

motor and the gear shift lever is actuated by a weighted rocker arm driven by a separate motor, and the gears are pulled in and out of mesh without the use of a clutch. Each set of test gears used in this machine consists of a countershaft and a sliding mainshaft gear heat treated simultaneously. The gear box is opened for inspection after the first 500 cycles and again after each additional 1000 cycles. The test is continued until chipping occurs, or until 8500 cycles are made. The countershaft gear has fewer teeth than the sliding mainshaft gear with which it meshes; consequently, it receives more abuse and fails first.

As already stated, it has been our practice for many years to carburize clash tooth gears on a reheat cycle. The outer portions of such a case consist of fine and medium carbides randomly distributed and a fine martensite with negligible amounts of retained austenite. It seemed desirable to minimize the retained austenite, since the plastic flow at the tips of clash gears would probably transform much of the austenite to brittle untempered martensite.

For reasons already cited we were forced to resort to direct quenching of boron-treated steels. Such gears did not stand up nearly so well in the clash testing machine as the reheated 8620 gears drawn at the same temperature (340° F.). However, we were able to obtain satisfactory chip resistance and surface hardness by raising the draw temperature to 375° F. to obtain a more ductile martensite, and by limiting the surface carbon concentration to minimize the amount of retained austenite. This procedure was adopted for production parts.

CONCLUSION

Experience gained through the processing of gears made from boron-treated steel has, we believe, contributed to our knowledge of the complexities involved in gear manufacture.

With few exceptions we have successfully manufactured heavy-duty transmission gears from 80B17 and 80B20 steel, insofar as physical properties and mechanical requirements are concerned. In many instances no processing changes have been required; in others the green dimensions had to be changed — particularly bore dimensions in splined gears. Hardenability of the case is considerably less than with 8620, while hardenability of the core is somewhat greater. Consequently, some variations in heat treating methods have been required to control distortion in light sections or to produce satisfactory case hardness in heavier sections.

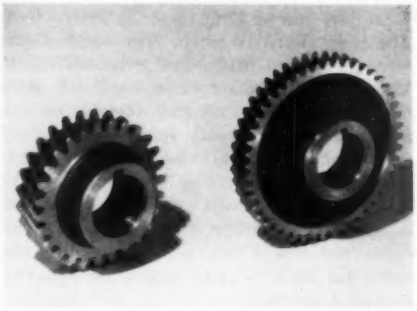


Fig. 9 — Two Gears That Were the Subject of Experimental Investigation. Gear at right is 6¾ in. diameter

We have learned that the sections involved are light enough so that the additional core hardness of 80B17 and 80B20 is of no value — is, in fact, detrimental, since it contributes appreciably to distortion. It is only logical to conclude, therefore, that a gear steel of low base hardenability but with alloy content sufficient to obtain the desired surface hardness of a carburized case would satisfy physical requirements and would be more practical and economical in manufacture. With this in mind, and anticipating the abandonment of the carburizing grades of the 80B00 series, we intend to use 8123* steel for gears or shafts of the lighter sections and 94B17 steel for the heavier sections. These have proven satisfactory to several large manufacturers.

It is significant that, as a result of the conservation program, most of the large industrial users of alloy steels have learned that they can appreciably reduce the amounts of nickel and molybdenum formerly used, either with or without the use of boron. It is hoped that metallurgists in general industry will follow this trend. It is doubtful if there ever will be a general return to original steel specifications after the present emergency is over.

*Same as 8122 except it is resulphurized to 0.035 to 0.050%. Its hardenability band is almost the same as the band for steel 8620H.

A New Research and Engineering Laboratory

By R. W. Schlumpf, Chief Metallurgist, Hughes Tool Co., Houston, Tex.

THE HUGHES TOOL CO. has completed the construction of new research and engineering laboratory facilities adjacent to its main office building in Houston, Tex. The laboratory has a front central two-story section with basement, flanked on three sides by a single-story structure with relatively high overhead clearance, as seen in the architect's perspective, Fig. 1.

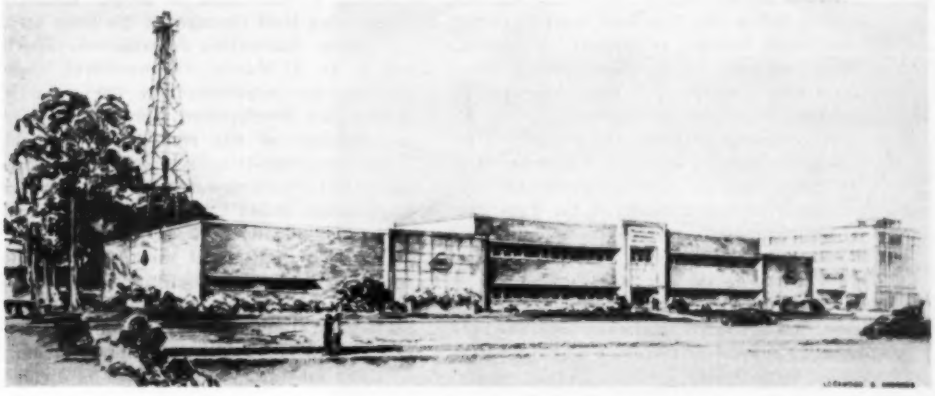
Offices, chemical, spectrochemical and metallographic laboratories along with the company library, a projection room, conference room, and smaller specialized laboratory rooms are contained in the two-story structure. The basement of this building houses the power distribution and air-conditioning equipment, locker and washrooms for shop personnel and several storage rooms. The surrounding one-story area will be used for laboratory-shop operations involving a wide variety of physical and mechanical testing, heat treating, welding and machine tool equipment. A mezzanine floor extending along the front wall of the shop area on each side of the two-story section provides additional workrooms and offices for technical personnel. The field-size drilling rig stands in the left rear corner of the building as a special unit of the laboratory. Frontage is 325 ft., depth 120 ft., and total floor area approximately 60,000 sq.ft.

The planning and construction of this laboratory involved several special features and requirements as follows:

Excessive vibration from some of the heavy testing operations necessitated special measures in the structural support and framing. Seismographic studies were made to determine the vibration characteristics of such equipment at the former location. These measurements were used in developing compensatory devices and in determining the foundation requirements to prevent resonance.

The drilling rig housing, with its roof at the same level as the shop area roof, appears externally to be achitecturally integral with the main building. This corner of the building, however, is a cut-away portion, a smaller unit with its own framing, column footing and derrick foundation isolated from the main building frame and foundation. This is effected by proper joint details as well as by cantilevering a short portion of the main roof framing between the two structures. Since the separation continues through foundation, grade-beams, walls, structural steel framing and roof, the direct transfer of vibration to the main structure is prevented.

Fig. 1 — Architect's Drawing of the Hughes Tool Co. Research and Engineering Laboratory



Laboratory Structural Features

Special foundations were also designed at other testing stations to minimize vibration. Treatment varies from simply bolting to the floor through absorbent pads to the use of floating substructure where the operation is characterized by heavy vibration or concussion.

The center and west portions of the building — seemingly a single unit — are separated by an expansion joint and double rows of columns to avoid the undesirable effects of expansion and contraction that might occur in a building of this size. This separation is further insurance against transmission of vibration to adjacent areas.

To insure a waterproof basement (of major importance in the Gulf Coast section), the subgrade soil is covered by a seal slab of concrete over which there is a waterproofing membrane continued to the outside of the basement walls. The basement walls and column footings are formed atop the seal slab. An interesting feature of this is the provision of 19 in. of sand fill over the waterproofed seal slab and underlying the structural slab for the basement floor. Future pipes can be installed without disturbing the seal slab by placing them in the sand fill after breaking through the structural floor slab.

The "Q-deck", used for the first and second floor of the office building, is of cellular construction providing approved raceways for ready adjustments in electrical wiring arrangements.

Steel framing is used except in the basement. Steel columns are used in the interior of basement, and the exterior steel columns above basement are supported sufficiently below the first-floor level to permit steel beam framing as support for the first-floor steel deck. In the office building, structural steel is fireproofed with masonry and lightweight insulating plaster.

A capacity of 1500 kva. is provided for the large electrical load that will be involved. The shop areas are lighted with incandescent and mercury vapor lamps of the dual type. Steam, oxygen, acetylene and compressed air are piped to the laboratory from central manufacturing plant facilities.

Because the shop contains many special machines and tools, particular care has been given to relative humidity in addition to the usual temperature control. Auxiliary air-conditioning service is available for the spectrochemical laboratory to meet the extremely close temperature and humidity tolerances for this type of equipment. Chilled water from a centrifugal refrigerating plant in the basement circulates to each of the air-conditioner coils through a reverse-return circulating system. Each conditioner contains a hot water coil on the exit side of the chilled water coil for reheating in the positive control of relative humidity.

Air conditioning of the shop area is served by seven central-type units placed near the roof beams above the traveling cranes. Conditioner sizes and locations have been selected to match the loads expected in the various sections of the shop; each unit creates its own zone of temperature and humidity control in its area. Using a number of complete air-conditioning units in this manner eliminates the movement of large volumes of air between departments in the laboratory and avoids the possible troubles that might arise if air recirculates from the welding and heat treatment sections across other areas in the shop. The chemical laboratory on the second floor of the office structure is served by a separate central conditioner (with exhaust hoods over all apparatus producing fumes), thereby avoiding recirculation of air from this individual laboratory into the other systems in the office building. The corner of the laboratory housing the operating platform of the drilling rig also has its separate conditioner.

The interior color scheme effectively employs a variety of pastels ranging from the yellow-greens to blue-greens. Cream tile walls with blue-green ceiling, in combination with mercury vapor-incandescent dual lighting, provide light of proper intensity at working level throughout the shop area.

Three engineering departments, reporting to D. J. Martin, vice-president, engineering, are responsible for the research, design and development work involved in manufacture of the company's products. These departments are research engineering, under F. L. Scott, research director; product engineering, under L. L. Payne, chief engineer; and metallurgical engineering, under R. W. Schlumpf, chief metallurgist. The Hughes Tool Co. Research and Engineering Laboratory functions as a division of the metallurgical department. Heading this division is W. R. White, laboratory director.

The laboratory organization is divided

into groups or units, each of which handles a particular classification of work under a group supervisor. At the present time, these groups are as follows:

1. Specialized mechanical and physical testing operations.
2. Metals group, responsible for conventional physical testing, heat treating, melting, metallography and photography.
3. Chemical laboratory.
4. Welding laboratory.
5. Machine shop.

In addition to the group supervisors, the organization includes several project engineers who are assigned to supervise the detailed work involved in major individual projects or investigations.

The mechanical and physical testing group and the project engineers assigned to it are largely concerned with the testing of product parts or product assemblies under conditions simulating the actual oil-field drilling service. Many of the machines used for this work (shown in Fig. 2) are designed by the group to meet a specific test requirement related directly to the conditions imposed on the part or assembly in actual service. The equipment for fatigue testing of full-size drill-stem connections (inset, Fig. 2) and the various methods employed to test resistance to different types of abrasion are of particular interest. Machines designed and built to test antifriction as well as plain bearings, under variable loading and rotational speed while being flushed with an abrasive-laden fluid, might be placed in the category of abrasion testing equipment. Many of the investigations conducted with these machines are primarily related to durability under heavy loading and might be only incidentally concerned with abrasion resistance.

The objective in most of these specialized tests is to improve service life of the product through new materials and processes or through the modification of materials or processes that are already in use.

Needless to mention, the

Organization and Work Classification

field-size drilling rig, with its derrick height extending 118 ft. above ground level, is the most important individual unit of equipment that might be classified under the bracket of "special mechanical testing". This drilling rig can be regarded as a separate laboratory in itself; the substructure or cellar at ground level (about 15 ft. beneath the rotary or working floor of the derrick) becomes the laboratory workroom in which the operator is able to observe and measure rock bit performance. The "drillability" characteristics of the various types of formations encountered in oil-well drilling are represented by test blocks nominally 4 ft. square by 5 ft. long procured from quarry locations in various parts of the country. In certain instances, synthetic blocks may be poured in molds from concrete employing aggregate specially sized for a particular test. Smaller

Fig. 2 — Special Machines Designed by the Mechanical and Physical Testing Group Simulate Service Conditions. Equipment shown in lower photograph is used to test bearings under variable loading while flushed with abrasive-laden fluid. Inset shows fatigue testing machine for full-size drill-stems

pieces or inserts of harder rock of varying sizes and shapes are sometimes poured within the concrete block for studying bit performance on composite structures.

The individual block to be used for the test is moved into this laboratory room and secured to the table, which in turn is mounted on steel ways that facilitate movement of the table in two directions through hydraulic mechanisms. The operator can quickly position the drilling block under the bit by manipulating the proper controls on the instrument panel. The instrumentation provides for control and measurement of variable axial loading on the drilling bit up to 100,000 lb., variable rotational speed up to 400 r.p.m., measurement of bit penetration over a total vertical travel of 5 ft. at rates up to 100 ft. per hr., and torque, along with the several controls over the standard oil-field mud pump and other accessory equipment. An item of special equipment is the penetration-rate measuring device designed and built by laboratory personnel. A splashproof observation balcony has been provided for the convenience of visitors at this highly interesting installation.

The ceiling of this drilling laboratory room is the derrick floor, carrying a 17½-in. oil bath rotary, driven through V-belts by a 100-hp. d.c. motor. A 100-kw. motor-generator set with 15-hp. motor-generator exciter unit furnishes direct current for the rotary drive motor. The 30-ft. drive-stem assembly to which the bit is attached is specially constructed from 10¾-in. casing with a 6¼-in. o.d. by 2¼-in. i.d. drill collar suspended inside the casing. Load is applied to the bit by a hydraulic pulldown yoke through a thrust bearing mounted near the top of the drive assembly. One of the special features of this drive is an arrangement for deflecting the stem through various angles to as much as 10° from the vertical position while drilling. Supplementing this drilling equipment, another section of the laboratory houses a smaller drilling unit capable of applying loads up to 50,000 lb. at speeds up to 90 r.p.m. through a vertical travel of about 12 in.

In the areas allocated to the metals groups are modern heat treating furnaces, atmosphere control equipment, induction melting units, magnetic-particle inspection equipment, latest research-type metallographic and photographic equipment, both still and motion, and the usual assortment of machines for making conventional physical tests. A new macro-etching installation designed by this group is of particular interest. The metals group devotes a substantial part of its time to routine laboratory operations related to the metallurgical material and process controls involved in the company's manufacturing operations. In this work the metals group functions as a service unit to the project engineers who might be assigned to contact duty with the manufacturing divisions in establishing and maintaining the proper controls on metallurgical operations and equipment in the company's various production shops.

Fig. 3 — Section of Metallographic Laboratory. Darkroom is behind wall with opening for passing prints to drum washer beneath shelf

A number of welding processes are used in the company's manufacturing operations. The welding laboratory is equipped to make experimental investigations related to the materials and equipment involved in the production welding. This group does a large amount of work with the various hard facing materials that play such an important part in oil-well drilling. Trial tests of new welding equipment are made here before a decision is reached to install the equipment on

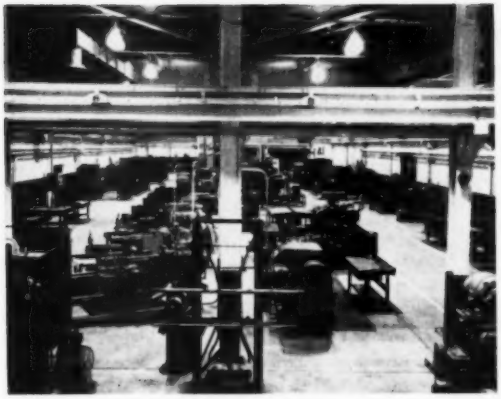


Fig. 4 — Machine Shop Builds Drilling Tools and New Equipment for Preliminary Testing, as Well as Special Testing Machines and Devices

the production line. New or different welding and brazing materials are likewise piloted in this laboratory before adoption in manufacturing operations.

The chemical laboratory is well equipped for handling an extensive field of analytical procedures. This group has an important role in control work, as in production carburizing and hardening operations, where a comprehensive analytical program effectively contributes to the maintenance of high product quality. Control work in connection with production electroplating operations is another important responsibility. The latest type of direct-reading spectrochemical instrumentation is used here for rapid production analyses and for the determination of elements that would be time-consuming by other analytical procedures.

The machine shop, which occupies a comparatively large area, differs considerably from the usual laboratory machine shop in its work schedule. If we regard the full-size product test model of a rock bit, tool joint or other drilling tool as a "test specimen", we can then assign major importance to preparation of specimens. In building a model of a full-size production bit for preliminary testing on the drilling rig, this group often calls on the metals group for carburizing or heat treating operations, and on the welding group for hard facing and assembly welding. The shop group handles a large amount of work for the research engineering department in building new

Machine Shop "Test Specimens"

designs, new mechanisms and new devices that are requisitioned for preliminary testing or other experimental work. Many of the special testing machines and devices employed by the mechanical and physical testing group are built by the machine shop group.

The research and development efforts that go into a new product or into the improvement of an existing product of the Hughes Tool Co. are activated through one or more of the three previously mentioned engineering departments and coordinated by the engineering administration division under the direction of P. G. Reeve. The initial step might be the development of a new design on the drafting board, a requisition to the laboratory for experimental work on a new type of material, or for testing a new process or a new piece of equipment. Full-size test models are constructed by the laboratory, or the investigational work will be assigned to one or more of the laboratory's technical groups, or to a project engineer who acts as coordinator where the job is large enough to require the services of more than one technical group. The new design, material or process will be tested in the laboratory and might be further modified and retested before releasing for field trials. These experimental products are then returned to the engineering laboratory where they are disassembled and a thorough study is made of the condition of the product in relation to the performance data.

A separate area is set aside within the shop part of the engineering laboratory and equipped for handling the many product items that are routed back for examination in accordance with the various project schedules. The casual observer would be impressed by the large volume of work that is done here but might fail to recognize the particular importance of the daily routine in this laboratory unit, where the final engineering data are obtained for writing the conclusion of the report covering the individual engineering project. The factual evidence obtainable here is invaluable to the staffs of the three engineering departments in successfully concluding the many projects concurrently in progress.

By F. P. Zimmerli, Chief Engineer, Barnes-Gibson-Raymond Division
of Associated Spring Corporation, Plymouth, Michigan

Spring Failures and Their Causes*

WHENEVER a spring fails it is usually sent to the metallurgical department for an explanation. "Why did it break?" Our experience indicates that more springs are broken through faulty engineering design than the metallurgist can ever explain.

Such being the case, a few simple rules will do much to determine the cause of breakage. It is often possible to look at the fracture and know whether it was caused by fatigue or not. If the fracture appears to be from fatigue, simple formulas for compression or extension springs have been devised to determine the stress.

These formulas are for extension or compression springs:

ROUND WIRE	SQUARE WIRE
$\text{Stress} = \frac{8PD}{\pi d^3}$	$\text{Stress} = \frac{9PD}{4d^3}$

where P = load in lb.
D = mean diameter, in.
d = wire diameter or side of square, in.

When a value of 120,000 psi. is encountered, the engineering department should be notified and asked to consider a redesign. Certainly high stresses and long life are incompatible.

On torsion springs of round wire, using the same nomenclature we have

$$\text{Stress} = 10.2\frac{PD}{d^3}$$

wherein a stress over 180,000 will not give a life of infinite length — that is, a million reversals or more.

If we have a flat cantilever spring of rectangular section, the same safe stress applies but the formula becomes

$$S = \frac{6PL}{bh^2}$$

where P = load in lb.
L = length of lever arm, in.
b = width of spring, in.
h = thickness in direction of applied load

Diagrams are available which plot the dimensions of steel springs working at high stresses for continued service. For compression springs of round wire a factor Y for curvature must be applied to the formula, if we wish to determine the stress at which the spring will have infinite endurance. This factor Y can be scaled from the curve shown in Fig. 16.

From the calculations employing this method, the minimum and maximum loads which the springs will carry can be converted to corresponding stress. These can then be laid on the Goodman diagram for that particular spring material (as shown in Fig. 11 of the previous installment) and, if the safe ranges given are not exceeded for quality carbon or alloy steel wire, no trouble should be anticipated. It should be remembered that when the maximum load is considered it must be the maximum *service* load, and not a figure from a blueprint which considers static, not operating, loads. Also remember that stresses in bends and in hooks on extension springs often exceed the calculated stress in the coils by 40%.

ENDURANCE LIMIT OF VALVE SPRINGS INDEPENDENT OF STEEL'S ANALYSIS

For cantilever springs of rectangular stock, Fig. 17 should be self-explanatory. The question naturally arises why there is a difference in the load-carrying capacity with size in the flat spring steel, and not in wires of different diameters. Why, when the tensile properties of wire increase (as with heavier cold drawing into fine diameters) does not the fatigue value also increase for infinite life? Here, unfortunately, we have a little trouble in giving logical answers; nevertheless our testing machines show larger tensile values with no better endurance.

We have found no difference in the endurance of wires at 0.020-in. and 0.207-in.

*The third and concluding portion of the 1951 William Park Woodside lecture before the Detroit Chapter entitled "Metallurgy in the Mechanical Spring Industry". The first, discussing the metal used for mechanical springs, was printed in the May issue of *Metal Progress*, and the second section covering heat treating, setting and shot-peening appeared in June.

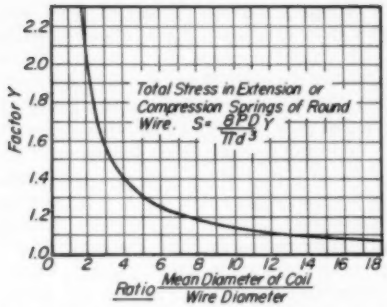

Factor Y
Total Stress in Extension or Compression Springs of Round Wire. S= 8PD/πd³ Y
Ratio Mean Diameter of Coil / Wire Diameter

Fig. 16 — Factor Y for Correcting Formula for Stress in Springs Made of Round Wire

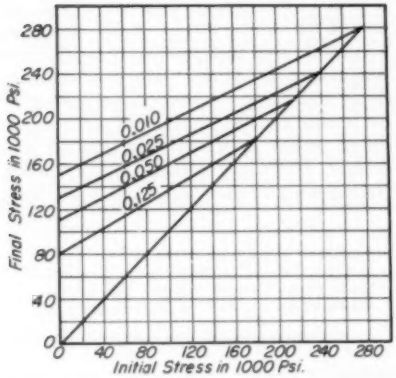


Fig. 17 — Safe Endurance Limits for Flat Springs of Thickness Indicated, When Made of 0.65 to 0.80% Carbon Steel Hardened to C-45 to 48 and Tested as Cantilevers

size in the flat part of the S-N curve. It is true that the smaller, stronger wires will stand a higher static load or a few loadings at higher stress without set than larger wire sizes, but that is all.

Furthermore, it is also true that in the small wire sizes, say ⅜ in. or less, with equally good surface and other metallurgical characteristics, there is no difference in the endurance of alloy steel and carbon steel. Music wire, size 0.162 and smaller, is equal to but no better than straight carbon tempered steel if heated to 750° F. to develop maximum endurance. The S-N curves for shot-peened springs of these materials, as given in Fig. 18, converge and become horizontal at 135,000 psi. Some day, without doubt a logical explanation of this phenomenon will be found.

If, now, unpeened strings are put in the test machine, initially stressed to 20,000 psi. (corrected for curvature), and run to find the endurance limit, we can break music wire, carbon valve-spring wire, chromium-vanadium valve-spring wire and chromium-silicon valve-spring wire at between 90,000 and 100,000 psi. This, considering accuracy of the testing machine, is to all intents the same thing. Again, we can only surmise that all these wires are equal either because the original surfaces are alike, or plastic flow during the test makes all the surfaces equal. Certainly the structure, tensile values, analysis, and method of manufacture are different.

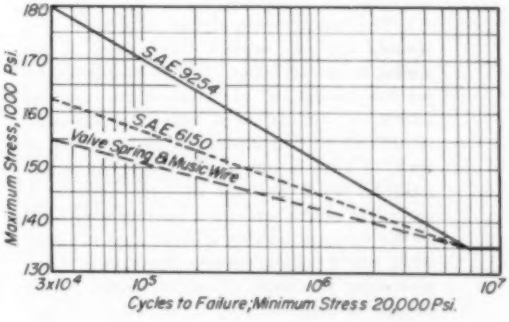
From this we learn that for actual infinite fatigue life a change in the *kind* of steel (for the sizes indicated) will be of little or no help, even though for short life (less than 100,000 stress applications) some variation in fatigue resistance can be expected from one steel to another.

SURFACE AND SUBSURFACE DEFECTS

Continuing with the subject of breakage, the metallurgist may find that there is a "step break" in the spring and conclude, therefore, this is a metallurgical flaw. If this conclusion is correct, the flaw can be on the surface or under the surface. For diagnosing this type of failure properly, good judgment is necessary.

Surface defects include hardening cracks, seams, laps, and damage from pits, die marks and tool marks. Of these, the Magnaflux will locate only the first three with certainty. The other defects must be found by careful

Fig. 18 — S-N Curves for Shot-Peened Springs Made of Two Alloy Steels and Two Varieties of Carbon Steel Wire, 0.148 In. Diameter



Spring Failures by Corrosion

inspection of the raw material, usually by etching both ends of each bundle of wire and by visual examination of the finished springs. The unfortunate part of this procedure is that the small, sharp pits or marks may be overlooked, while the broad, round-bottom marks which are harmless are very easily seen. Thus, there is a tendency — which should be corrected by proper inspection — to reject harmless faults and pass over the more dangerous. It must be remembered that no wire is perfect and at proper magnification the best material made shows a very rough surface.

Often a step break will appear in a part that, on etching, shows a smooth surface. The chances are that either a pit or an extremely short crack or seam caused the trouble. When peening with grit or poorly screened cast iron shot, a particle will sometimes be driven so hard against the spring it produces as sharp a pit as if a needle had been driven into it. A step fracture will result and there is no indication of its cause. Pits may also form in the wiredrawing process or may be caused by rust accumulating on the material in storage or from poor pickling at the wire mill. These usually occur in more than one place on a spring so the cause of trouble can be surmised.

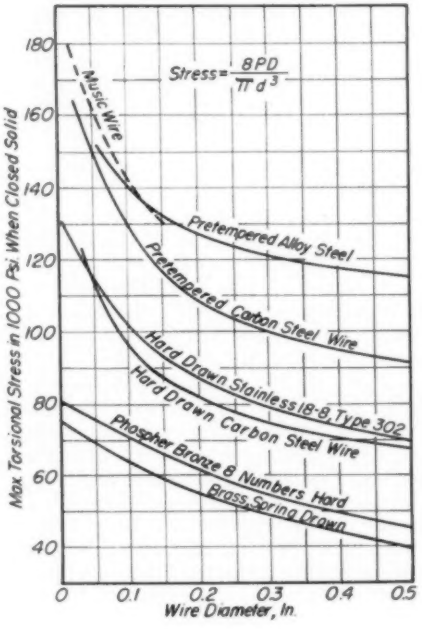
Corrosion is a more common cause of spring breakage than is usually appreciated by the user. It is caused in most valve springs by condensation of the products of combustion. A little pit is formed, or there is hydrogen embrittlement from the oxidation of the steel. It is revealing to know how fast this breakage may be. Perfect springs have been made to fail in 3 to 6 hr. in an overcooled motor, or in one that was started and stopped before it could run long enough to scavenge the crankcase.

The usual methods to overcome this trouble are *(a)* protect the surface of the spring from corrosion, *(b)* use stainless steel for the springs, or *(c)* remove the cause of corrosion. In any event, failure by corrosion is difficult to detect because the little pit or fleck of rust is not easily seen. An unbelievably small amount of corrosion on a spring in active use, as a valve spring, can do the damage, leaving a break that is somewhat like a regular fatigue fracture. When corrosion is likely to occur, every effort should be made to stop it, as failure is certain in highly stressed springs in rapid use. Under static conditions this is not necessarily so. Springs have rusted out as much as three quarters of the wire diameter (with, of course, gradual load loss) without actually breaking as long as they were not called upon to move.

Vibrating springs which depend on shot-peening to supply them with the additional endurance necessary will fail if this peening is improperly done or the stressed surface removed by corrosion. The fracture will be that of a typical fatigue failure. Visual examination at 5 to 10 diameters will ascertain if the parts have proper coverage. If not, then they must be peened over again.

Since heating will remove the compressive stresses of peening, as given in Fig. 12, p. 105 of the June issue of *Metal Progress*, it is essential that this possibility be checked in diagnosing any failure. Mechanical force, such as stretching a compression spring to make it long enough, or bending a cantilever beam to change its shape after peening, has been known to cause breakage. Parts must be reprocessed if such work has been done

Fig. 19 — Maximum Stress Before Failure by Set of Compression Springs Made From Various Wires. For extension springs use 80% of plotted stresses



on them, to insure that the stress distribution in the finished spring is correct.

Failure to Function From Setting or Load Loss — Springs fail for functional purposes if they set and lose load. The first and usual cause is heat. The temperature and the stress under which the spring operates are not at a point of equilibrium, as shown in the graphs published in former portions of this paper. Deliberate overloading at room temperature will cause setting.

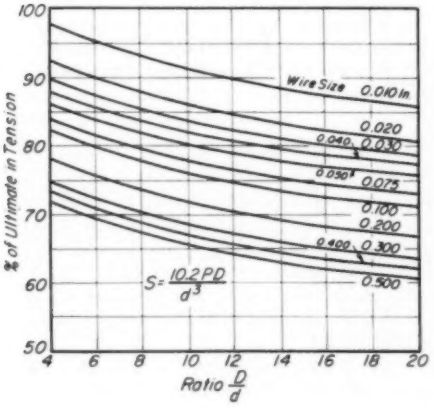
If springs are designed for a very limited life, using the highest possible stress to conserve material, we find failure by set will occur in compression springs if the values given in Fig. 19 and 20 are exceeded. Figure 19 is for compression springs of round wire; Fig. 20 is for torsion springs of round wire.

From Fig. 20 we see that the *size* of the wire — reflected in its ultimate strength — is important in the setting of torsion springs. The higher this mechanical property, the greater the load-carrying ability. This lines up with normal expectancy, and in that respect is much different from the flat portion of the S-N diagram of Fig. 18.

Improper heating after forming will cause set. This is because the stresses which augment those imposed on the spring by the loading are not removed.

Shot-peened springs will, under temperature, set much more than unpeened springs. If failure by setting is encountered, heating to 750 to 800° F. will remove the peening stresses and the tendency to set. Here, the metallurgist must balance the spring life between fatigue failure and setting failure, which is often a difficult decision to make.

Fig. 20 — Apparent Stress in Torsion Springs Made of Round Wire Where Permanent Set Begins



Improper Heat Treatment is infrequent but should be considered when diagnosing a spring failure. If springs are overheated, the grain structure will be coarse and the fatigue life poor. Failure to heat to a proper temperature or long enough to get all of the carbides into solution prior to quenching for hardening will result in ferrite patches in the microstructure and a low endurance limit. Automatic time-temperature control in modern heat treating departments has almost completely eliminated this once-common cause of breakage.

Plating often is a cause of failure in springs due to induced hydrogen embrittlement. This can occur in the plating operation but more often is due to acid pickling before plating. The practice is very dangerous and should be avoided. Occasionally, springs will safely endure acid cleaning, one heat being more sensitive than another, but sooner or later the control fails and trouble starts. No plated spring has quite the endurance of the unplated spring under noncorrosive conditions of test or service. Cadmium is better than zinc, in that it affects spring life less.

Phosphate Coatings do not leave spring steel in as good condition as before, desirable though they may be for other purposes. For example, if a bare spring, Rockwell C-45 hard, is put in a vise it could be bent 90°. After the phosphate treatment, about 60° would be the most that could be expected.

Decarburization is the most infrequent offender in all the list of defects. Slight decarburization is frequently present in spring wire, and is often blamed for failures which could be properly attributed to surface defects or poor design. Actual tests have shown that properly made, shot-blasted valve springs have the same life whether slightly decarburized or not, provided no large ferrite areas are present. Various steels used in valve springs do not all act the same in regard to this condition. The silicon steels such as 9254 or 9260 usually are decarburized more in the wire mill than carbon steel, but decarburization has much less effect on the fatigue life of the springs made therefrom.

A ring of ferrite around the wire circumference is a basis for rejection, for it is a possible cause of failure. Such a condition

is not tolerated in valve-spring wire and is practically never encountered in wire or springs made with modern equipment.

Usually a slight partial decarburization is more of a help than a hindrance. More trouble will be encountered from higher carbon or nitrogen content on the surface causing quenching cracks or high notch sensitivity than from partial decarburization. The slightly more ductile surface often allows some adjustment of stress raisers on the most highly loaded part of the material. It can be taken as a rule that some decarburization will be found if searched for under high enough magnification, but in almost every instance where partial decarburization is credited with spring failure we have a metallurgist looking for an excuse, not a reason, for the trouble he is in.

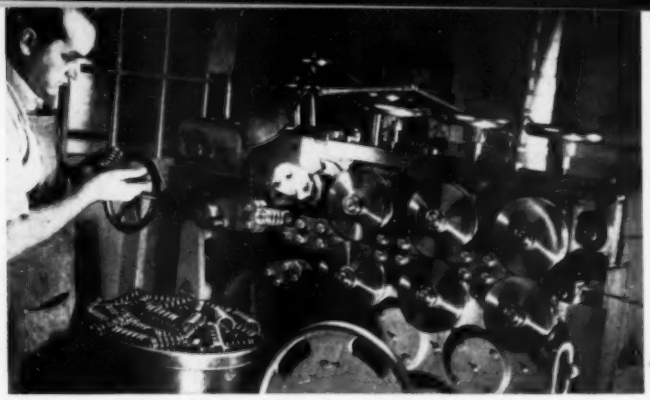


Fig. 21 — Automatic Spring Coiling Machine

CONCLUSION

In closing, let us all strive to be metallurgists in the best sense of the word. Know the product, know the material, and, lastly, known the limitations of both. Any rule-of-thumb inspector can reject or accept a piece of steel on a chemical or Rockwell test. It takes an educated, scientific and engineering mind to use or not to use material.

Only by exerting thorough knowledge of what can and must be used and not by hiding behind arbitrary figures can our profession be advanced to its rightful place. We must exercise authority over materials, their selection and use. When the metallurgist fails to have complete responsibility for jurisdiction over the metallurgical field, he is merely a part of some department and not an executive.

This is what William P. Woodside, founder member of the American Society for Metals, sought to avoid with education years ago. The battle is not won yet, so let us resolve to carry it on.

Critical Point

BY THE EDITOR

Corrosion Studies at "Sea Horse Institute"

On North Carolina's Atlantic coast and about 50 miles from its southernmost tip are two unique testing stations where International Nickel Co. is collecting data on marine corrosion. Here competing industries, educational and governmental groups are banded in the search for the answers to this problem, and once a year an informal conference is held at the Harbor Island laboratory, jocularly called the "Sea Horse Institute".

Obviously, much good has come of these activities; exposure of test pieces to the usual salt solutions or even to synthetic sea water gives, at best, only a rough measure of the resistance of a metal to attack by natural sea water. More than 15,000 specimens have been tested in sea water while the number exposed to seashore atmosphere is over 20,000.

All of this was started a little over 15 years ago when Frank L. LaQue put a

couple of samples in the intake channel to Ethyl-Dow Chemical Corp.'s sea-water bromine plant at Kure Beach. It seems that these were in the water hardly long enough for the nearest barnacle to swim to them when Frank's associates at Inco had already learned of the test and had jumped into his briny experiment; their "couple of samples" became a dozen, and soon this dozen was multiplied. News of this ocean test-tube spread quickly; other producers of metals submitted samples and the project became a cooperative venture. In 1940 racks for atmospheric tests at 800 ft. from shoreline were installed and, shortly after, other sets 80 ft. from the shore were added for sea-spray studies. Storm damage to the jetties in 1950 required construction of new facilities and these were built on Harbor Island, which is about 15 miles north of Kure Beach and near Wilmington, N. C. Harbor Island lies to the lee of two islands and almost opposite the narrow inlet of the sound, a location well protected from the fury of ocean storms. Other advantages of this location are that the sea water is uncontaminated by industrial wastes, water temperature ranges from 45 to 85° F., and there is a relatively long season for growth of many marine organisms.

Adjoining the main laboratory building is a large dock-like structure supported by wood and steel piles, each of which is a test piece in itself. The wood is treated to prevent marine fouling and to guard it from marine borers. The steel is covered with some corrosion-inhibiting surface such as coal-tar enamel or vinyl paints, hot dipped or sprayed metallic coatings, Monel or 70-30 copper-nickel sheathing (the high copper for its anti-fouling properties). Sheathing may be applied by cladding, welding and mechanically fastened wrappings at the critical tidal and splash zones. In addition, some of the pilings are cathodically protected by wiring them to magnesium anodes.

Some of these investigations are a continuation of earlier work at Kure Beach on the distribution of corrosion when a portion of the steel, as in pilings, is sometimes wet and sometimes dry. According to Frank LaQue, director of the corrosion engineering section, under such conditions of immersion the surfaces exposed to the air during the interval between tides become cathodic to the underwater surfaces and, when the tide is in, a current flows from the underwater surfaces to those at the tidal region so that corrosion of the latter is reduced. This was shown by a sample that was pitted approximately 60% less at the tidal region than at the continuously submerged portion, and about 50% less than the surfaces continuously exposed to the air.

Part of the dock at Harbor Island is used to expose scale models and full-size units of marine equipment such as water and oil coolers. Walkways give access to the racks holding panels of smaller specimens. It was in a test of this kind that the corrosion-preventive effect of chromium with and without nickel and other elements was determined for sea-water exposure. Thus, panels of 3, 6, 13, 15 and 17% chromium-iron alloys, and Types 304, 18-8 Mo, 18-8 Ti and 18-8 Ag were tested for depth of pitting and total weight loss. (The silver, it may be recalled, was supposed to form an inhibiting deposit of insoluble silver chloride as in any incipient pit.) Barnacles and other marine organisms became attached to these steels and caused serious pitting when the chromium content exceeded 3%. In the austenitic family best results were obtained with 18-10 containing 3% Mo.

At the sea-spray test lot, steels containing up to 9% Cr were covered with consider-

(Continued on p. 124)

Piling Test Specimens, Held in Place by Porcelain Insulators, Are Exposed to Marine Corrosion and Fouling for Periods Ranging From 6 Months to Several Years

Correspondence

British Commentary on American Steelmaking

LONDON, ENGLAND

The Editor of *Metal Progress* was kind enough to say that my impressions of American steelmaking practice, derived from participation in the tours preliminary to the First World Metallurgical Congress, would be interesting to members of the American Society for Metals.

From reports of previous visitors and from the published literature I was prepared to find plants very advanced as regards mechanical equipment and handling devices. What was particularly impressive was the *speed* at which the machinery was operated — and it seems to me that this matter of speed of plant operation must be clearly linked with the energetic safety propaganda found everywhere in America. In British works there is much less outward evidence of a safety program, yet I doubt whether the accident rate is any greater. If, however, we speeded up our machinery to the same extent, no doubt we should find it necessary to be much more aggressive in this respect.

At the risk of repeating what every visitor must have said, I would like to add my tribute to the friendliness with which the American steelworks opened up their plants and gave information so freely. It certainly makes visitors like myself very anxious to repay some of this kindness by giving back information in return. Perhaps one such direction may be in exchange of experience on how to make steel with poor raw materials.

One thing which always impresses a British steelmaker visiting America for the first time is his American counterpart's good fortune in raw material supply. I inquired the analyses of the blast furnace iron in most of the plants and answers "In the region of 0.03% S and 0.30% P" came with almost monotonous regularity. Ample supplies of natural gas and of fuel oil containing less than 1% sulphur added to my envy. When I returned home and found my colleagues making good quality, deep-drawing sheet steel from iron containing 1.50% phosphorus and 0.08% sulphur, and with fuel oil containing 2.50% sulphur, I felt that our industry had a good answer to some of its critics. Also large tonnage of ores containing under 30% iron is smelted in Britain.

This raw material question is one on which I feel there may be an eventual chance of Britain repaying some of the technical advice which has been so freely given by our American friends, for America may at some time find herself faced with a serious deterioration in raw materials.

A. H. LECKIE
Head of the Steelmaking Division
British Iron & Steel Research Assoc.

German Commentary on American Steelmaking

VOELKLINGEN, SAAR

One of the most evident things about American industry is the scale and speed of production. For example, at Ford's Rouge plant a completed automobile leaves the production line every 90 sec. One blast furnace at Bethlehem's Sparrows Point plant produces as much as our whole line of six furnaces at Voelklingen — 54,000 tons per month. At Gary, 21,000 workers produce 6,000,000 tons of steel annually!

In my opinion such high production in tons per worker and per hour can only be achieved by constant quality, by good mechanical equipment, by big furnace and industrial units, by highly skilled labor, and by thorough study of the individual jobs.

The steel refining plant of our Voelklingen works in the Saar can compare in equipment and in quality of output but not in size with specialized steel refining plants such as Crucible Steel's Sanderson and Halcomb Works in Syracuse, N. Y., which have about 3000 workmen and produce 5000 tons of electric steel per month. The continuous rolling of bars, shapes and wire rod of high speed steels, toolsteels and especially alloy steels is notable. The product is very straight and has a good surface.

It was told that these Syracuse plants were notable for the quality of the product.

I observed very little cleaning; none of the billets required chipping at intermediate stages after the ingots (especially the stainless steels) were chipped and ground very carefully at defects, either by portable equipment or by machine tools. There are few pickling baths, and no sandblasting, but the product is carefully checked for flaws by magnetic or supersonic devices similar to those that we use.

I can summarize my observations as follows: Besides huge plants there are others which correspond to European conditions or to our works in Voelklingen. We can compete in quality of steel produced in every respect with the American plants which we visited. However, to avoid unproductiveness we must study more carefully the individual processes and mechanize to a greater extent to reduce manual labor.

For instance, when an American open-hearth furnace is torn down for a new lining and roof, a bulldozer is used to clear the site. Furnace linings are repaired with a dolomite gun and very seldom by hand — else the furnace is rebuilt. In the casting bay a bulldozer shoves scrap away from the ladle pit, or a crane loads big pieces directly into railroad cars.

The American considers his hands as his greatest asset; everywhere in the plants there are precautions against accidents.

I am impressed by the purchasing power of the American steelworker — not so much in terms of money as in terms of hours of labor. For example, a second-hand automobile, adequate to take the owner from home (which may be the unheard-of distance of 25 miles away), can be had for 200 hours of labor. A pair of stout work shoes costs four hours. A suit of "Sunday" clothes 25 hr. Three pounds of coffee or three dozen eggs for one hour!

Despite these prices, and the opportunity for buying such luxuries as automatic refrigerators and television sets, Americans work diligently. I have been told that in America, also, money doesn't grow on trees!

I noticed that the Americans don't work in their homes or gardens as much as we do in the Saar. Therefore our homes look much prettier, situated in a fruit or vegetable garden with many flowers, and not on a bare lawn without a fence or hedge.

PHILLIP L. F. RÖLLER
Vice-Chief of Steel Control
Roechling'sch Eisen und Stahlwerke

Modified Picral for Higher Alloy Steels

HARRISON, N. J.

During an investigation of the transformation characteristics of low-carbon, 12% chromium stainless steels, we found that some of the microstructures encountered could not be satisfactorily developed when conventional etching solutions, including the 2% zephiran chloride – picral solution, were employed. Some of the structures encountered in these steels could be developed satisfactorily if the amount of zephiran chloride was increased from 2 to 10%; however, the 10% zephiran chloride – 5% picral reagent did not behave in a consistent manner.

The assumption was made that the function of the zephiran chloride might be to provide chloride ions. Therefore, a number of chlorides which showed some solubility in ethyl alcohol were added individually to 5% picral. The addition of a small amount of any of these produced a satisfactory etchant for 12% chromium steels.

Because it is perhaps more convenient to add liquid HCl dropwise than to weigh out small amounts of the solid chlorides, HCl was used to modify the picral solution.

The optimum amount of HCl in picral varies with the alloy content and structure of the steel to be etched. For the 12% chromium steels only 3 to 6 drops were required in 50 cc. of 5% picral, corresponding to ¼ and ½% HCl by volume. The micrograph in Fig. 1-A shows that good contrast between the tempered martensite and delta ferrite in hardened and tempered Type 410 can be developed by using a ½% HCl – 5% picral solution.

The conventional 5% HCl – 1% picral solution, on the other hand, does not behave like ordinary picral. It provides less contrast between the two phases, but develops the details of martensite grain structure which are not obtained by the ½% HCl – 5% picral solution. This is illustrated by Fig. 1-B. The contrast between the tempered martensite and delta ferrite shown in this figure is about the maximum obtainable with the 5% HCl – 1% picral reagent. A longer etching time over-etches the specimen. Although the activity of picral increases with increasing HCl, contrast is decreased.

Figure 2-A illustrates that a ¼% HCl – 5% picral solution can show an inhomogeneity in composition which is not indicated

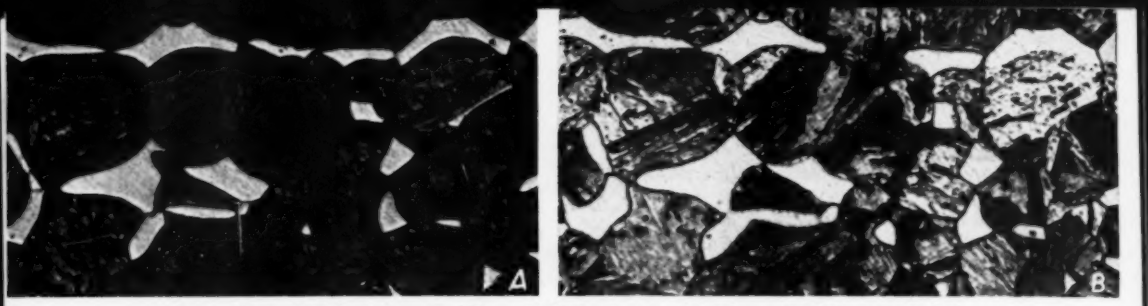


Fig. 1 — Type 410 Water Quenched From 1800° F., Tempered 2 Min. at 1050° F. (A) Etched 2 min. in ½% HCl – 5% picral. (B) Etched 30 sec. in 5% HCl – 1% picral. 750 ×

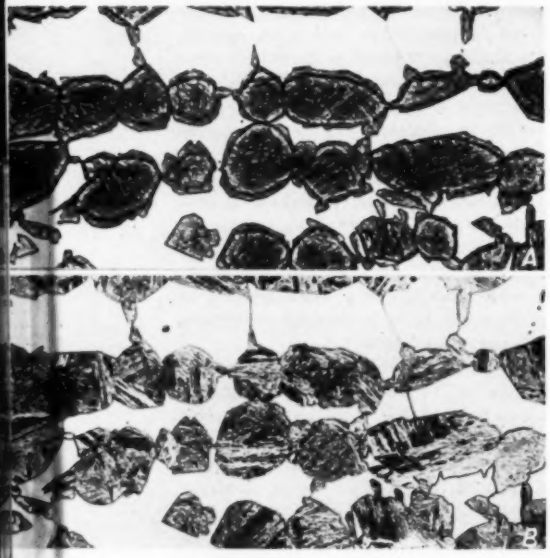


Fig. 2 — Type 410 Water Quenched From 2400° F., Tempered 2 Min. at 1050° F. (A) Etched 3 min. in ¼% HCl – 5% picral. (B) Etched 30 sec. in 5% HCl – 1% picral. 250 ×

Fig. 3 — (A) Etched 3 Min. in ¼% HCl – 5% Picral. (B) Etched 30 sec. in 5% HCl – 1% picral. 750 ×

by 5% HCl – 1% picral, in this example the periphery of the areas of tempered martensite being etched in a different manner from the core. On the other hand, the 5% HCl – 1% picral solution develops the grain structure of the martensite as in Fig. 2-B.

Figure 3 illustrates the structure of a sample austenitized at 1800° F., quenched into a bath at 640° F., and held for 1 min., then transferred immediately to 1100° F. and held 30 min. to temper (darken) the martensite. The dark-etching martensite in Fig. 3-A denotes areas that transformed during cooling from 1800 to 640° F. That the conventional 5% HCl – 1% picral solution does not provide much contrast between tempered and untempered martensite areas in Type 410 is shown in Fig. 3-B.

There is no single concentration of HCl in picral which is optimum for all steels. Increasing amounts of HCl decrease both the etching time and contrast. As a general rule, maximum contrast is obtained when the HCl addition is such that an etching time of 1 to 3 min. is required. The addition of only one drop of HCl to picral is as effective as 2% zephiran chloride. We prefer the HCl addition because we encounter less trouble caused by staining with this modification.

A. E. Nehrenberg
Supervisor
Research Laboratory
Crucible Steel Co. of America

Correction

Attention has been called to two printing errors in the article on "Influence of Gas Composition and Flow on Carbo-Nitrided Cases", by W. H. Holcroft and D. J. Schwalm, in the April issue of *Metal Progress*.

In Fig. 3 on page 92 the figure for amount of nitrogen should be 0.0144 g. instead of 0.9144. The caption for Fig. 4 should read "Excessive rate of flow of atmosphere has no effect on carburizing action, and slightly *increases* the nitriding action." The printed caption states that it *reduces* nitriding action, although the effect is correctly described in the text.

Foundrymen Discuss Shell Molding and Ductile Iron

By Harold J. Roast, Foundry Consultant, London, Ont.; Consulting Editor for Metal Progress

IT HAS BEEN the Consulting Editor's privilege to spend two weeks in an exhilarating metallurgical atmosphere. In the first week he attended the Naval Foundry Conference at the Norfolk Navy Shipyard, where the host was Rear Admiral D. H. Clark, commander of the yard. Here were foregathered the Navy's master molders from Pearl Harbor to Portsmouth. Their main concern is the casting of metal and the development of efficient foundry organizations. In addition, a dozen or more civilian experts on various phases of the art and science of metallurgy responded to invitation to lend their knowledge to the group.

The next seven days were spent at the International Congress of the American Foundrymen's Society at Atlantic City, under the presidency of Walter L. Seelbach. Here several thousand Americans held a series of technical sessions. About a hundred men from 11 countries overseas were also in attendance. While the thinking of both groups — the small one at Norfolk and the large one at Atlantic City — was similar, the Congress had the advantage of appealing to the eye as well as to the ear. In the large and important Foundry Show new processes in actual operation could be witnessed and readily appreciated in about 265 exhibits.

One general theme was predominant at both localities — improved castings of higher dimensional accuracy at lower cost. (In fact, that has always been the aim of foundry engineering and technology.) These two gatherings paid a lot of attention to a relatively new process, "shell molding", and a relatively new material, "ductile iron". At Atlantic City one session was devoted to the operation of the basic cupola, particularly in regard to the melting of ductile iron.

Behind both activities, those of the Navy and industry, was the urge to improve the national defense. The part played by applied research was in evidence in both gatherings. In each, improvement was sought in accuracy and increase in physical characteristics. *Speed* of production was perhaps more the thought of industry. The desire for teamwork was the outstanding quality of Navy and industry alike, and every evidence of leadership could be seen in both groups.

The visitor cannot but be impressed by the size and activity of the Norfolk Shipyard as it is today. It was established nearly two centuries ago. Its forerunner was the Gosport Shipyard of Andrew Sprowle, started in 1767, and the flag of Great Britain flew over it until 1775, when the flag of Virginia was hoisted. In 1794 the Stars and Stripes became the official banner, and in 1861 the flag of Virginia and of the Confederacy briefly commanded until the port was captured by Union forces in 1862.

The Yard at present has a ground area of some 900 acres, with 4½ miles of sea front. It has a covered floor area of about 4,500,000 sq.ft., uses nine switching locomotives on 40 miles of railway track, and employs some 45,000 men when at capacity.

NORFOLK NAVY CONFERENCE

At the opening of the Norfolk conference, Capt. R. E. W. Harrison, U. S. N. Bureau of Ships, stressed the point that the Navy is now, as always, considering new ideas — as an instance, the coming use of stainless steel propellers in place of the long-used manganese bronze. There is no indication that the relative tonnage of castings in the ships of tomorrow will decrease — rather the hope is that the foundries will so raise the quality of their output that *more* will be used. For example, he could not see why the recently developed nodular cast iron should not replace almost entirely the cast iron parts now used in ships.

As would be expected, much of the discussion at Norfolk centered on operational problems other than metallurgical. For example, H. Edsall of Birdsboro Steel Foundry and Machinery Co. summarized the advantages of cement-sand mixtures, long used by his firm for molding large steel castings, and

known as the Rand-Upson process. E. D. Boyle, master molder of Puget Sound Shipyard, called attention to the volcanic mineral perlite, which, when puffed up into a flour-like mass by quick heat, is an excellent insulating collar and cover for risers; he quoted thermocouple records showing liquid metal in risers four times as long as otherwise. Proper gating and risering for bronze pressure castings were considered by James R. Power ⊕ of Portsmouth Navy Yard, and all present agreed that designer, patternmaker, and foundryman must cooperate early in the day if real progress is to be made in the production of pressure castings — and for that matter, of all castings. Numerous instances were cited where production economies could be effected and utility enhanced by adopting aluminum bronze or silicon bronze in place of the traditional Navy "G" or "M" metal where special resistance to sea water is unnecessary.

Ceramic Molding is a new competitor for the attention of progressive foundrymen, and its advantages were presented by H. H. Harris ⊕, president of Alloy Engineering and Casting Co. Much of his work in this line was done in a research contract with the Navy, and has already been outlined in past issues of *Metal Progress*. He is convinced that if metal is properly melted free of gas and other inclusions, poured at optimum *sustained* temperature, at optimum speed and pressure (enhanced centrifugally, if necessary), into clean and properly gated molds containing no combustible or gas-forming constituents, of high degree of dimensional accuracy, and of controlled heat conductivity — then the as-cast crystalline structure would have a maximum variation of about one tenth that existing in commercial sand castings, and the metal *in the casting* would consistently have tensile properties at least 25% better than demanded of separately cast test bars in present specifications.

Propellers are of course a characteristic, important and far-from-simple item of naval gear. Mare Island Naval Shipyard alone has totaled up about 3000 tons of propellers — some requiring up to 100,000 lb. of molten metal. A favorite alloy is manganese bronze (39% Zn, 0.75% Sn, 0.5% Mn, 1% Al, 1.25% Fe) melted in a reverberatory furnace, and tapped at 1850° F. A go-ahead test consists of $\frac{5}{8}$-in. trapezoidal bars, cast in an iron mold, and shaken out as soon as possible — some immediately quenched, others air cooled

Fig. 1 — Metal Is Poured Simultaneously From Four Ladles Into a Mold to Make a Platen for a 14,000-Ton Hydraulic Press. (Courtesy Bethlehem Steel Co.)

for 5 min. When bent around a 2½-in. pin the air cooled bars should not fracture until bent more than 120°; the quenched bars should fracture *before* reaching 20° else tensile and yield will be low and more zinc should be added to the furnace. Metallographically, the casting itself consists of 25-75 mixture of alpha and beta phases with particles of primary iron compound well distributed.

Development of methods and materials for propellers is by no means halted. For maximum properties and utility a manganese-aluminum bronze (Navy specification 46B-29) and nickel-copper-silicon bronze (Navy specification 46N-7) are recommended for investigation. High-chromium steel (12 to 14% chromium) is also recommended on account of its high yield and tensile strength and adequate ductility (reduction of area and per cent elongation).

Before passing on to a brief account of the Atlantic City convention, it may not be amiss to record the impression that the naval personnel represented the highest type of American foundrymen. The formal presentation and the general discussion were as good as you get anywhere. Free interchange of thought and experience was the order of the day. Naval practices are by no means static; new processes get careful attention. The men of the Navy Yards were anxious to hear of the advanced industrial practices because they have to compete, cost-wise, with industry for any work that comes within the capacity of outside foundries.

SHELL MOLDING

At Atlantic City a symposium on shell molding attended by nearly 1000 persons was held under chairmanship of Bernard M. Ames, senior metallurgist of the New York Naval Shipyard. He also spoke at length on this subject the previous week in Norfolk, where he reinforced his remarks by an extensive display of molds, techniques and castings made during his studies of the process — a good example of the care and thoroughness with which this governmental agency worked out the practical aspects of a new process. (A rather detailed critique of this work was presented by the present writer in *Metal Progress* for April 1952 — so recently that it is unnecessary to repeat.)

At Atlantic City the bonding resin manufacturers had much to say. H. K. Salzburg of the Borden Co. addressed the symposium on behalf of his company as well as the three others at the Congress — Dow-Corning, Monsanto and Bakelite. The common objective is to produce an adequate phenolic resin which will either cost less, be required in less quantity, or both. Various "release agents" were also promoted. A core binder with faster baking rate, free from the objectionable urea smell, and nonirritating to the skin, was displayed by Monsanto.

Patterns themselves require attention — they should have fairly uniform wall section, such as is used in architectural molding, so the heat transference to the resin-sand mixture shall be equally distributed. Further, the patterns should be given a very fine finish, even a polished surface. New patterns should be broken in by heating and applying the release agent several times before starting operations. It was brought out that shell molded cores are sometimes economical. They can be used for conventional molds in green or dry sand. They can be made to extremely close dimensions. R. W. Crannell of Lehigh Foundries, Easton, Pa., said that his firm had made over 300,000 such cores.

Investigations described by C. W. Blount, vice-president of Bakelite Division of Union Carbide and Carbon Corp., look toward the day when shell molding will become an automatic process.

Hand dusting and patching of the mold before baking have been eliminated. Flowing qualities of resins have been studied with the object of providing a good bonding material which sets rapidly. Another objective is to eliminate lubricants on the pattern plate. All lubricants leave a deposit on the pattern, so that the fewer applications needed during the day's run the better. Already one of their lubricants lasts for 20 molds instead of one.

It is this commentator's observation that shell molding is far from being a panacea for all foundry troubles — in fact, some of its limitations are obvious. On the other hand, it appears self-evident that the foundries, both industrial and naval, have a new tool that often will be very valuable.

DUCTILE IRON

International Nickel Co. is actively promoting ductile iron, by reason of its owner-

(Continued on p. 146)

Experimental Nuclear Explosions*

A TEST nuclear detonation, such as was recently demonstrated over Yucca Flats, Nevada, is not the culmination of an atomic test; it is approximately the halfway point. From the spectators' view it is the most spectacular of any of the revealed way points on the road to understanding nuclear weapons, but behind the spectacle there has been much scientific labor, and much is yet to be done after the burst.

Compelling reasons are behind experimental nuclear explosions. Fissionable materials are expensive and rare, and the cost of such operations must be sizable. Recognizing this, the Atomic Energy Commission has standardized a procedure of test approval which ultimately reaches to the President of the United States, who is the one man in the country with the power to approve a nuclear explosion.

The recent experiment at Yucca Flats was made primarily to determine blast pressures, and to measure the velocity of the air mass surrounding the point of detonation of the device being tested. It is not necessary for a "weapon" to be used in order to evaluate weapons, but the information obtained will help in their design. Here, then, is the primary point of test shots — more efficient use in weapons of fissionable materials.

The calculation of the energy released from an exploding critical mass is not yet solved. Before the first test at Alamogordo, in 1945, an attempt was made to predict the energy release from the detonation, using all the then-available information about such atomic processes. The results of the calculation predicted only half of the amount actually measured when the bomb went off. Recently, the scientists worked the same problem again, and predicted an energy release for that first bomb which was twice that actually measured! This is proof of the need for actual experiment to answer fundamental questions.

For any test, weather conditions are of concern. Not only must the weather be clear for an air drop (radar aiming is not used for the drops), but wind currents must also be known, to prevent the atomic cloud from drifting over populated areas. Data from Alaska, Japan, Hawaii, ships at sea, as well as regular weather bureaus, are all used to predict conditions at the test site.

Protection of participants, as well as those outside the test areas, is another scientific activity. The Atomic Energy Commission's Biology and Medicine Division studies effects of radiation and sets standards and working conditions for those exposed. The task of protecting the troops on the bombed Nevada desert, and all persons living within 200 miles, fell to a Radiological Safety Unit.

One of the most fascinating scientific studies used is that of predicting where the blast from the atomic bomb will go and where it will create damage. Atomic Energy Commission has at times been surprised at the blast damage bombs do at considerable distances, while closer areas are completely unscathed.

Correspondents were given a glimpse of the control point at Yucca Flats and of a typical bunker in the bomb area which houses recording instruments. Bunkers are built of concrete below ground level, and are covered with a thick mound of earth, stabilized with an asphalt coating. Walls are about 3 ft. thick and doors are lead-filled to minimize radiation in the instrument room. Entrances are labyrinths, and each bunker is equipped with an air-cooling plant to remove the heat generated by the many instruments and motors operating during a test.

The detecting instruments for the most part are contained in test towers (300 ft. high). Coaxial cables transmit signals to the recording instruments in the bunker.

As for the blast itself, there is little to add to what has already been said. We chose to face away from detonation, and saw the desert grow white from the intense light of the nuclear release — some 35 to 40 times as bright as the sun, according to my calculations, where we stood. At the same instant, an intense heat wave was felt, of such power that one is thankful it lasted only a microsecond. After the first glare, the light dimmed, and I turned to face a fireball, turbulent and churning, red and black. This snuffed out quickly, and in its place was a colored cloud, doughnut-shaped, twisting and rising. The desert lifted in a huge dust cloud, and the expected mushroom formed, but not for long. The stem quickly broke and the cloud, now solid, rose, still pink, white and salmon, to a tremendous height — 40,000 ft., we learned later.

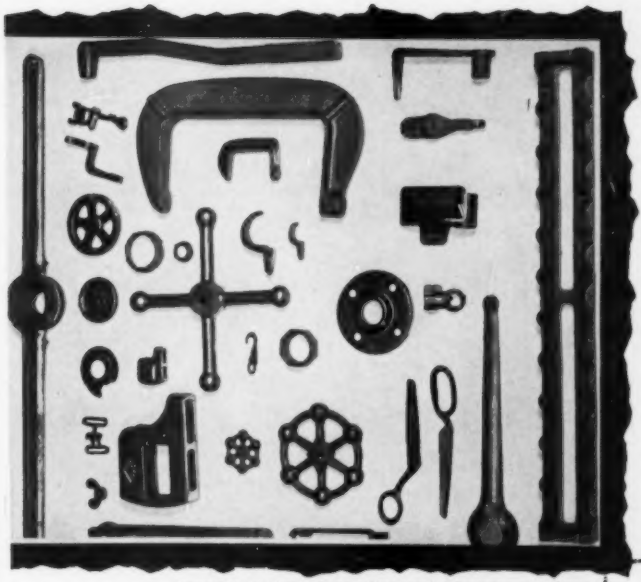
Somewhere during this time, the blast wave hit, loud and forceful, knocking my hat from my head. It came as a complete surprise, for though I knew of it, and had planned to time it, the events were such that when it came, it was unexpected. I suspect further that my mouth was still open in amazement and unbelief. After all, the instantaneous release of 2×10^{13} calories, just 10 miles away, is more than impressive; it is close to terrifying.

Half of "Operation Big Shot" was over. Now began the final phase of tracking, calculating, analyzing and deciding what science had learned; all pointing to the next experiment.

*Excerpts from a report to be published in full in *Chemical Engineering Progress* by F. J. Van Antwerpen, editor. Mr. Van Antwerpen is a member of the A. E. C. Advisory Committee on Technological Information.

PRODUCT AND PROCESS ADVANTAGES

increase demands for Ductile Iron



COURTESY OF ACME SHEAR COMPANY, BRIDGEPORT 1, CONN.

Ductile Iron offers excellent castability, high mechanical properties and good machinability. Castings show superior pressure tightness, good elastic modulus and resistance to shock. They range from those weighing a few ounces . . . with sections as thin as one-tenth of an inch . . . to 50-ton anvil blocks with sections 4' thick.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 WALL STREET, NEW YORK 5, NEW YORK

DUCTILE IRON PROVIDES mechanical properties which approach those of cast steel. In addition, it combines the *machinability and wear-resistance* as well as the *fluidity and castability* of cast iron.

Presence of spheroidal rather than flake graphite not only gives this new material ductility that is unique among cast irons, but contributes much to its other exceptional properties.

REMARKABLE CHARACTERISTICS OF DUCTILE IRON

1. Its elastic modulus, about 25,000,000 psi, is virtually unaffected by composition or thickness . . .

2. It can provide a chilled, carbidic, abrasion-resistant surface supported by a tough ductile core.

3. As-cast ductile iron of 93,000 psi tensile strength has the same machinability rating as gray iron with a strength of 45,000 psi.

4. Annealed ductile iron can be machined at a rate 2 to 3 times that of good quality gray iron.

5. It can be satisfactorily welded.

6. It resists oxidation and growth to an extent never before available in gray iron castings.

7. It can be cast in intricate shapes not normally feasible for cast steel.

AVAILABILITY

Send us details of your prospective uses, so that we may offer a list of sources from some 100 authorized foundries now producing ductile cast iron under patent licenses. Request a list of available publications on ductile iron . . . mail the coupon now.

INCO

The International Nickel Company, Inc.
Dept. MP, 67 Wall Street
New York 5, N. Y.

Please send me a list of publications on:
DUCTILE IRON

Name_____ Title_____

Company_____

Address_____

City_____ State_____

A.I.S.I. Standard Alloy Steel Compositions

A.I.S.I. List Revised March 25, 1952

Openhearth and Electric Furnace Alloy Steels

(Bars, Billets, Blooms and Slabs)

A.I.S.I. Number *(a)*	C	Mn	Ni	Cr	Mo
1320	0.18-0.23	1.60-1.90	.....	.....	.....
1321 *(b)*	0.17-0.22	1.80-2.10	.....	.....	.....
1330	0.28-0.33	1.60-1.90	.....	.....	.....
1335	0.33-0.38	1.60-1.90	.....	.....	.....
1340	0.38-0.43	1.60-1.90	.....	.....	.....
2317	0.15-0.20	0.40-0.60	3.25-3.75	.....	.....
2330	0.28-0.33	0.60-0.80	3.25-3.75	.....	.....
2335	0.33-0.38	0.60-0.80	3.25-3.75	.....	.....
2340	0.38-0.43	0.70-0.90	3.25-3.75	.....	.....
2345	0.43-0.48	0.70-0.90	3.25-3.75	.....	.....
E2512 *(c)*	0.09-0.14	0.45-0.60	4.75-5.25	.....	.....
2515	0.12-0.17	0.40-0.60	4.75-5.25	.....	.....
E2517 *(c)*	0.15-0.20	0.45-0.60	4.75-5.25	.....	.....
3115	0.13-0.18	0.40-0.60	1.10-1.40	0.55-0.75	.....
3120	0.17-0.22	0.60-0.80	1.10-1.40	0.55-0.75	.....
3130	0.28-0.33	0.60-0.80	1.10-1.40	0.55-0.75	.....
3135	0.33-0.38	0.60-0.80	1.10-1.40	0.55-0.75	.....
3140	0.38-0.43	0.70-0.90	1.10-1.40	0.55-0.75	.....
3141	0.38-0.43	0.70-0.90	1.10-1.40	0.70-0.90	.....
3145	0.43-0.48	0.70-0.90	1.10-1.40	0.70-0.90	.....
3150	0.48-0.53	0.70-0.90	1.10-1.40	0.70-0.90	.....
E3310 *(c)*	0.08-0.13	0.45-0.60	3.25-3.75	1.40-1.75	.....
E3316 *(c)*	0.14-0.19	0.45-0.60	3.25-3.75	1.40-1.75	.....
4017	0.15-0.20	0.70-0.90	.....	.....	0.20-0.30
4023	0.20-0.25	0.70-0.90	.....	.....	0.20-0.30
4024 *(d)*	0.20-0.25	0.70-0.90	.....	.....	0.20-0.30
4027	0.25-0.30	0.70-0.90	.....	.....	0.20-0.30
4028 *(d)*	0.25-0.30	0.70-0.90	.....	.....	0.20-0.30
4032	0.30-0.35	0.70-0.90	.....	.....	0.20-0.30
4037	0.35-0.40	0.70-0.90	.....	.....	0.20-0.30
4042	0.40-0.45	0.70-0.90	.....	.....	0.20-0.30
4047	0.45-0.50	0.70-0.90	.....	.....	0.20-0.30
4053	0.50-0.56	0.75-1.00	.....	.....	0.20-0.30
4063	0.60-0.67	0.75-1.00	.....	.....	0.20-0.30
4068	0.63-0.70	0.75-1.00	.....	.....	0.20-0.30
4118	0.18-0.23	0.70-0.90	.....	0.40-0.60	0.08-0.15
4130	0.28-0.33	0.40-0.60	.....	0.80-1.10	0.15-0.25
E4132 *(e)*	0.30-0.35	0.40-0.60	.....	0.80-1.10	0.18-0.25
E4135 *(e)*	0.33-0.38	0.70-0.90	.....	0.80-1.10	0.18-0.25
4137	0.35-0.40	0.70-0.90	.....	0.80-1.10	0.15-0.25
E4137 *(e)*	0.35-0.40	0.70-0.90	.....	0.80-1.10	0.18-0.25
4140	0.38-0.43	0.75-1.00	.....	0.80-1.10	0.15-0.25
4142	0.40-0.45	0.75-1.00	.....	0.80-1.10	0.15-0.25
4145	0.43-0.48	0.75-1.00	.....	0.80-1.10	0.15-0.25
4147	0.45-0.50	0.75-1.00	.....	0.80-1.10	0.15-0.25
4150	0.48-0.53	0.75-1.00	.....	0.80-1.10	0.15-0.25
4317	0.15-0.20	0.45-0.65	1.65-2.00	0.40-0.60	0.20-0.30
4320	0.17-0.22	0.45-0.65	1.65-2.00	0.40-0.60	0.20-0.30
4337 *(f)*	0.35-0.40	0.60-0.80	1.65-2.00	0.70-0.90	0.20-0.30
4340 *(f)*	0.38-0.43	0.60-0.80	1.65-2.00	0.70-0.90	0.20-0.30
4608 *(g)*	0.06-0.11	0.25-0.45	1.40-1.75	.....	0.15-0.25
4615	0.13-0.18	0.45-0.65	1.65-2.00	.....	0.20-0.30
E4617 *(h)*	0.15-0.20	0.45-0.65	1.65-2.00	.....	0.20-0.27
4620	0.17-0.22	0.45-0.65	1.65-2.00	.....	0.20-0.30
X4620	0.18-0.23	0.50-0.70	1.65-2.00	.....	0.20-0.30
E4620	0.17-0.22	0.45-0.65	1.65-2.00	.....	0.20-0.27
4621	0.18-0.23	0.70-0.90	1.65-2.00	.....	0.20-0.30
4640	0.38-0.43	0.60-0.80	1.65-2.00	.....	0.20-0.30
E4640	0.38-0.43	0.60-0.80	1.65-2.00	.....	0.20-0.27
4812	0.10-0.15	0.40-0.60	3.25-3.75	.....	0.20-0.30
4815	0.13-0.18	0.40-0.60	3.25-3.75	.....	0.20-0.30
4817	0.15-0.20	0.40-0.60	3.25-3.75	.....	0.20-0.30
4820	0.18-0.23	0.50-0.70	3.25-3.75	.....	0.20-0.30
5045	0.43-0.48	0.70-0.90	.....	0.55-0.75	.....
5046	0.43-0.50	0.75-1.00	.....	0.20-0.35	.....

A.I.S.I. Number *(a)*	C	Mn	Ni	Cr	Mo
5117	0.15-0.20	0.70-0.90	.....	0.70-0.90	.....
5120	0.17-0.22	0.70-0.90	.....	0.70-0.90	.....
5130	0.28-0.33	0.70-0.90	.....	0.80-1.10	.....
5132	0.30-0.35	0.60-0.80	.....	0.75-1.00	.....
5135	0.33-0.38	0.60-0.80	.....	0.80-1.05	.....
5140	0.38-0.43	0.70-0.90	.....	0.70-0.90	.....
5145	0.43-0.48	0.70-0.90	.....	0.70-0.90	.....
5147	0.45-0.52	0.70-0.95	.....	0.85-1.15	.....
5150	0.48-0.53	0.70-0.90	.....	0.70-0.90	.....
5152	0.48-0.55	0.70-0.90	.....	0.90-1.20	.....
5155	0.50-0.60	0.70-0.90	.....	0.70-0.90	.....
5160	0.55-0.65	0.75-1.00	.....	0.70-0.90	.....
E50100	0.95-1.10	0.25-0.45	.....	0.40-0.60	.....
E51100	0.95-1.10	0.25-0.45	.....	0.90-1.15	.....
E52100	0.95-1.10	0.25-0.45	.....	1.30-1.60	.....
6117	0.15-0.20	0.70-0.90	.....	0.70-0.90	0.10 min. V
6120	0.17-0.22	0.70-0.90	.....	0.70-0.90	0.10 min. V
6145	0.43-0.48	0.70-0.90	.....	0.80-1.10	0.15 min. V
6150	0.48-0.53	0.70-0.90	.....	0.80-1.10	0.15 min. V
6152	0.48-0.55	0.70-0.90	.....	0.80-1.10	0.10 min. V
8615	0.13-0.18	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25
8617	0.15-0.20	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25
8620	0.18-0.23	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25
8622	0.20-0.25	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25
8625	0.23-0.28	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25
8627	0.25-0.30	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25
8630	0.28-0.33	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25
8632	0.30-0.35	0.70-0.90	0.40-0.70	0.40-0.60	0.15-0.25
8635	0.33-0.38	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8637	0.35-0.40	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8640	0.38-0.43	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8641 *(d)*	0.38-0.43	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8642	0.40-0.45	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8645	0.43-0.48	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8647	0.45-0.50	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8650	0.48-0.53	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8653	0.50-0.56	0.75-1.00	0.40-0.70	0.50-0.80	0.15-0.25
8655	0.50-0.60	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8660	0.55-0.65	0.75-1.00	0.40-0.70	0.40-0.60	0.15-0.25
8715	0.13-0.18	0.70-0.90	0.40-0.70	0.40-0.60	0.20-0.30
8719	0.18-0.23	0.60-0.80	0.40-0.70	0.40-0.60	0.20-0.30
8720	0.18-0.23	0.70-0.90	0.40-0.70	0.40-0.60	0.20-0.30
8735	0.33-0.38	0.75-1.00	0.40-0.70	0.40-0.60	0.20-0.30
8740	0.38-0.43	0.75-1.00	0.40-0.70	0.40-0.60	0.20-0.30
8742	0.40-0.45	0.75-1.00	0.40-0.70	0.40-0.60	0.20-0.30
8745	0.43-0.48	0.75-1.00	0.40-0.70	0.40-0.60	0.20-0.30
8747	0.45-0.50	0.75-1.00	0.40-0.70	0.40-0.60	0.20-0.30
8750	0.48-0.53	0.75-1.00	0.40-0.70	0.40-0.60	0.20-0.30
9255 *(i)*	0.50-0.60	0.70-0.95	.....	.....	.....
9260 *(i)*	0.55-0.65	0.70-1.00	.....	.....	.....
9261 *(i)*	0.55-0.65	0.75-1.00	.....	0.10-0.25	.....
9262 *(i)*	0.55-0.65	0.75-1.00	.....	0.25-0.40	.....
E9310	0.08-0.13	0.45-0.65	3.00-3.50	1.00-1.40	0.08-0.15
E9315	0.13-0.18	0.45-0.65	3.00-3.50	1.00-1.40	0.08-0.15
E9317	0.15-0.20	0.45-0.65	3.00-3.50	1.00-1.40	0.08-0.15
9437	0.35-0.40	0.90-1.20	0.30-0.60	0.30-0.50	0.08-0.15
9440	0.38-0.43	0.90-1.20	0.30-0.60	0.30-0.50	0.08-0.15
9442	0.40-0.45	1.00-1.30	0.30-0.60	0.30-0.50	0.08-0.15
9445	0.43-0.48	1.00-1.30	0.30-0.60	0.30-0.50	0.08-0.15
9747	0.45-0.50	0.50-0.80	0.40-0.70	0.10-0.25	0.15-0.25
9763	0.60-0.67	0.50-0.80	0.40-0.70	0.10-0.25	0.15-0.25
9840	0.38-0.43	0.70-0.90	0.85-1.15	0.70-0.90	0.20-0.30
9845	0.43-0.48	0.70-0.90	0.85-1.15	0.70-0.90	0.20-0.30
9850	0.48-0.53	0.70-0.90	0.85-1.15	0.70-0.90	0.20-0.30

NOTE *(a)* — Numbers with prefix E are made in basic electric furnaces and unless otherwise noted the following specifications hold: Phosphorus 0.025% max., sulphur 0.025% max., silicon 0.20 to 0.35%.

Numbers without letter prefix are ordinarily made in basic openhearth furnaces and unless otherwise noted the following specifications hold: Phosphorus 0.040% max., sulphur 0.040% max., silicon 0.20 to 0.35%.

Specification limits for the acid electric and acid openhearth processes are: Phosphorus 0.050% max., sulphur 0.050% max., silicon 0.15 to 0.35%.

In all processes the maximum allowable quantities of unspecified and incidental elements are as follows: 0.35% copper, 0.25% nickel, 0.20% chromium and 0.06% molybdenum.

NOTE *(b)* — For 1321 the phosphorus and sulphur are both 0.050% max.

NOTE *(c)* — When this steel is made in openhearth furnaces the manganese is 0.40 to 0.60%.

NOTE *(d)* — Resulphurized steel; sulphur in 4024 and 4028 is 0.035 to 0.050%; in 8641 it is 0.040 to 0.060%.

NOTE *(e)* — When this steel is made in openhearth furnaces the molybdenum is 0.15 to 0.25%.

NOTE *(f)* — When this steel is made in electric furnaces the manganese is 0.65 to 0.85%.

NOTE *(g)* — Silicon is 0.25% max.

NOTE *(h)* — For openhearth steel the molybdenum is 0.20 to 0.30%.

NOTE *(i)* — Silico-manganese steels; silicon range is 1.80 to 2.20%.

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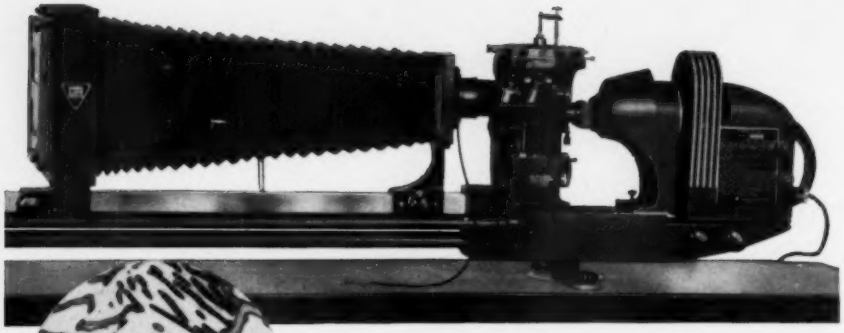

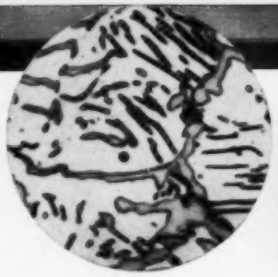

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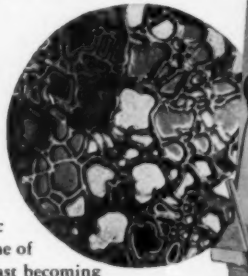

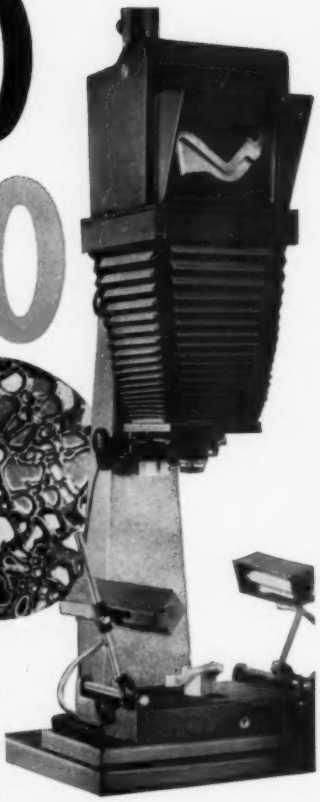

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Engineering Principles and Metal Requirements for Atomic Power Plants

By W. J. Koshuba and V. P. Calkins, Respectively Head, Metallurgy and Ceramic Development Groups, and Head, Metallurgical Research and Chemistry Groups, of the Materials Section, Aircraft Nuclear Propulsion Project, General Electric Co., Oak Ridge, Tenn.

ENGINEERS, as a class, would do well to ask themselves, "Why should we be concerned with nuclear power plants?" They should weigh their answers carefully. The rapid and efficient development of future stores of useful power will depend to a large extent upon their answers. Nuclear power plants cannot be built without their help; consequently, the engineer himself must become conversant with the underlying principles. Since the materials of construction pose the biggest problems, the development of nuclear power plants should be of special concern to the metallurgical engineer. He should assume a prominent role in this field.

But before we get into this subject very far it might be well to present an elementary review, and for the main facts we turn to the source book: H. D. Smyth's "A General Account of the Development of Methods of Using Atomic Energy for Military Purposes Under the Auspices of the United States Government, 1940-1945".* As a result of innumerable experiments between 1900 and 1940 with naturally radioactive elements and on others bombarded by fast streams of electrical particles, artificially prepared, it was generally accepted by physicists and chemists that every atom consists of a small, heavy nucleus carrying an integral number of positive charges (protons), surrounded by a largely empty region in which an equal number of very light electrons, each carrying a negative charge, move somewhat like planets about the sun. The nuclei of all atoms except hydrogen also contain at least as many uncharged particles of mass (neutrons) as there are protons. Thus, magnesium, element No. 12, atomic weight 24, has an atomic structure consisting of 12 protons and 12 neutrons in the nucleus and a planetary system of 12 electrons. This is noted by the symbolism $_{12}Mg^{24}$. The number and arrangement of electrons determine the chemical properties of the atom; the formation of chemical compounds is accompanied by minor rearrangements of the outermost electrons only, the atomic nuclei being unaffected. Furthermore, the nature of isotopes was explainable. For example, natural magnesium has an atomic weight of 24.32, and is a mixture of 78.6% $_{12}Mg^{24}$, 10.1% $_{12}Mg^{25}$, and 11.3% $_{12}Mg^{26}$, identical chemically because each has a system of 12 electrons, but the nuclei are different in weight, containing 12, 13, and 14 neutrons respectively in addition to 12 positively charged particles (protons).

Neutrons had been knocked out of beryllium atoms by the energetic radiation emitted from polonium, one of the naturally radioactive metals existing in nature, and being a fast-moving particle without electrical charge, it could penetrate the electrical field surrounding an atomic nucleus and reach the nucleus itself. If the bombarded atom were one of high atomic number — the very heavy metals — the nucleus captured the neutron and converted or transmuted itself into the next heavier element.

What would happen if uranium, the last and heaviest element completing the periodic table, were bombarded with neutrons? The experiment was performed by Fermi, the Italian, in 1934, but the results were not properly interpreted until 1939 by Frisch and Meitner (German refugees) — namely, that the atom split into two fragments. Later pre-War research showed that one of the fragments was $_{56}Ba^{138\pm}$. If barium's protons, neutrons and electrons were subtracted from those of uranium $_{92}U^{235}$, the remainder was more than enough to fit any of the elements of mass number 90. In other words, a cer-

*A 32-page condensation of this "Smyth Report", prepared by Ralph P. Johnson, was printed in *Metal Progress* for December 1945 under the title "Atomic Power and Atomic Bombs". Another excellent source of information is Samuel Glasstone's "Source Book on Atomic Energy", published in 1950 by D. Van Nostrand Co., New York.

tain amount of mass had been converted to energy and there were several extra neutrons. Here, then, was the possibility of a chain reaction which would generate enormous amounts of energy.

Our common sources of power, other than sunlight and water power, are chemical reactions releasing energy. Combustion is self-propagating; lighting a fire with a match releases enough heat to ignite the neighboring fuel, which releases more heat which ignites more fuel, and so on. Similarly, a self-propagating nuclear reaction must emit particles of the same sort which initiates it and in sufficient numbers to cause the reaction to proceed in neighboring nuclei. Consequently, the early work of the atomic bomb project was to determine whether such a chain reaction could indeed be achieved, for it must be remembered that natural uranium (element No. 92) is a mixture of two isotopes, 0.7% being $_{92}U^{235}$ which fissions when struck by a neutron, and 99.3% being $_{92}U^{238}$ which *captures* the neutron and transmutes into an artificial element, No. 94, now known as plutonium, $_{94}Pu^{239}$. Only a full-size experiment would determine whether too many of the neutrons emitted by fission of the minor portion (the 235 isotope) would be captured by the major portion (the 238 isotope) and so quench the reaction. Of course, this contingency could be avoided by separating U^{235} from U^{238} and this is being done on a large scale in our so-called diffusion plants. However, since, in all likelihood, the new element plutonium would be fissionable and therefore a valuable explosive, the experimental production of a chain reaction in natural uranium would pay double dividends.

It is obvious that the reactions are quite different from chemical reactions because they involve changes in nuclei of atoms rather than in their electronic structure; the energy changes are vastly larger than even those of the most violent chemical explosives, and the products are new atoms rather than new molecules. Since many, if not most, of the new atoms are unstable, considerable damaging radioactivity is associated with the reaction and its products.

The earliest investigations showed that neutrons emitted in the process of fission have a very high speed. The highest probability of capture (and fission) of U^{235} is when the neutrons are brought down to a slow

Fig. 1 — First Nuclear Reactor Under Construction. Alternate layers of graphite containing uranium slugs or cans of uranium oxide were spaced by layers of graphite. Layer 18, almost covered, contained uranium; layer 19, being added, contained none. "Critical" dimensions, wherein the chain reaction became self-sustaining, were reached with the 56th layer. When the 57th layer was completed the reactor was able to operate at a power level of 0.2 kw. The pile was roughly spherical in outline. (Courtesy of Argonne National Laboratory)

speed ("thermal neutrons", so called). At intermediate speeds U^{238} has a large chance of capturing neutrons and producing plutonium. Obviously, therefore, it would be well to slow down the neutrons immediately after their release. This is done by highly purified graphite (carbon blocks), wherein the process of slowing down is simply one of elastic collisions between rapidly moving neutrons and carbon atoms relatively at rest. The general idea was to place rods of uranium along the joints or in equally spaced holes in a pile of carbon blocks (Fig. 1). Fast neutrons escaping from one uranium rod would bump their way through several inches of graphite and eventually reach another uranium rod in a tired-out condition, easily capturable by another atom of U^{235} which would then immediately split and produce more fast neutrons.

It worked! It worked when the size got big enough so relatively few neutrons wandered from the system to the outside air or shield; most of them were captured before they escaped. Such a pile is an energy producer, principally through the fission of U^{235} (which loses a fraction of its mass) and the slowing down of the fast neutrons. An

operating pile or reactor must be kept cool in some manner. Most of the experimental piles operated by the U. S. Atomic Energy Commission are air cooled; the large piles for plutonium manufacture are water cooled. The problem of the atomic power plant is simply to convert this heat (ordinarily wasted) into some form of kinetic energy which can be utilized industrially. Of course the reactor may take other forms than the pile using graphite as a moderator — as will appear in the subsequent discussion.

THE GENERAL PROBLEM

There are two ways in which nuclear energy can be useful from a power plant viewpoint:

1. By competing with current fossil energy (coal, oil, gasoline).

2. By opening up new avenues not readily available to fossil energy.

For ordinary application one can hardly foresee that nuclear energy will be a strong competitor with fossil energy in the immediate future. This is based primarily on two reasons: First, the cost and scarcity of nuclear fuel at present are greater than chemical fuels; second, considerable inertia and complexity in the re-orientation of our present industrial perspective would have to be overcome in the transition to a new source of energy. However, in regions where no coal or water power is available, such as Argentina, the Mediterranean, Southern China, and desert regions in America and Africa, production of power by nuclear energy might be very feasible.

The present cost and scarcity of nuclear fuels are probably strong factors against their widespread use in the immediate future, but not necessarily for the more distant future. It has been stated that there are only 19,000 tons of natural uranium readily available in the world, 136 tons of which are the U^{235} isotope. This figure by itself is somewhat misleading, as it is based on our known deposits of comparatively high-grade ore. There are on the order of 10^{15} tons of natural uranium in the crust of the earth and 10^{10} tons more in the ocean. It is not inconceivable that some relatively inexpensive means of extracting the uranium from low-grade ores (such as the oil shales and the red granites) and even from the ocean can be discovered by the combined efforts of the engineer and the research scientist. Such development will take time.

The second way in which nuclear energy could prove useful from a power plant viewpoint is most intriguing. There have been several recent reports in technical or popular magazines, newspapers and books, dealing with nuclear power for submarines, ships, and aircraft. (A special presentation on problems pertinent to aircraft nuclear propulsion has recently been given by M. C. Leverett in an address before the Chicago Chapter of the Institute of Aeronautic Sciences, Oct. 4, 1951.) One of the main advantages associated with nuclear power and which has been stressed in these reports is that of unlimited range of the vessel so powered — not limited by the consumption of fuel but by the freedom of the vehicle and power plant from mechanical breakdown and the ability of the crew to endure long cruises

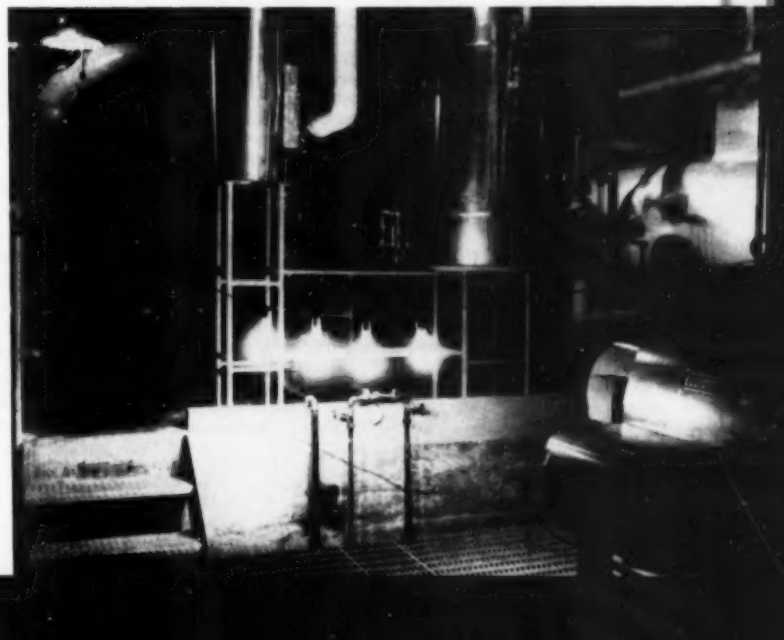

Fig. 2 — First Known Use of Electric Power From Atomic Energy. Four bulbs, lighted from electricity from generator in left foreground, driven by heat from experimental breeder reactor at National Reactor Testing Station in Idaho. (Eleventh Semi-Annual Report of the U. S. Atomic Energy Commission)

and subsequent long exposures to radiation. A nuclear powered aircraft could stay aloft for several days, encircle the globe several times without stopping, and perform these feats at its maximum operating speed and altitude without exhausting its fuel supply. A submarine could perform in a similar fashion completely submerged. The military advantages of these nuclear powered vehicles are quite obvious.

Despite its conceded value from a military viewpoint, nuclear energy as a source of power is probably too important to our civilization to have its development dictated solely by its use for military needs. It is quite possible that in some distant future, when our supply of fossil energy nears exhaustion, nuclear fuels may tide us over until photosynthetic or solar energy can be utilized. If the use of nuclear energy and solar energy for power purposes came of age simultaneously, it would be difficult to say which one might predominate. Probably it would depend upon their respective thermal efficiency and their ease of conversion into useful power sources, rather than upon their relative abundance.

Although the solar energy which falls upon the earth in one month equals twice the total energy represented by all the coal resources in all the earth, it would still take approximately 30,000 years for this solar energy to produce as much energy as could be produced from all the U^{235} in the earth's crust. Hence, it is apparent that both nuclear and solar energy represent vast potential sources for future power development, largely dependent on how well the engineers can mine the less readily available sources of uranium metal.

Although the first man-made nuclear reactor started operating at the University of Chicago on Dec. 2, 1942, it was nine years later (Dec. 20, 1951) that electrical energy was extracted from a nuclear reactor in any significant amount (Fig. 2). Nevertheless, nuclear power plants are not new but rather ancient — indeed, prehistoric — and are fundamental to our way of life. Life on our planet, Earth, could not exist without receiving the benefits of the chief nuclear reactor of our solar system — our relatively small star, the Sun. Together, the Sun and the Earth make up our most important nuclear power plant, the Sun serving as the nuclear reactor* and the Earth serving as a heat engine.

The slow development of terrestrial nuclear power plants is due primarily not to nature's refractoriness but more to the lack of concentrated effort expended on the problem. Engineers with an interest in the application of nuclear energy are sorely needed.

SOME ELEMENTARY CONCEPTS

Before discussing the general details of nuclear power plants, it might be advantageous to describe some elementary concepts associated with nuclear energy. For ready reference these concepts have been listed below in outline form and defined.

Nuclear Fuel — A nuclear fuel is a material capable of fissioning and giving rise to a nuclear chain reaction which is self-sustaining. There are three materials now known which are capable of undergoing fission from a practical utilization viewpoint: $_{92}U^{233}$, $_{92}U^{235}$ and $_{94}Pu^{239}$.

Reactor or Pile — In nuclear technology, the words "reactor" and "pile" are used interchangeably. A reactor consists of a nuclear fuel incorporated in a matrix body with definite geometric arrangements so that fissioning can occur.

Criticality and Critical Mass — A reactor is said to be critical when the resulting chain reaction is just self-sustaining. It is subcritical when the chain reaction tends to die out; it is overcritical when the chain reaction tends to increase continually toward self-destruction. "Critical mass" is the minimum quantity of nuclear fuel which will sustain the nuclear chain reaction.

*Editor's Footnote — The generally accepted view of the source of the sun's energy is the synthesis of helium from hydrogen — a reaction which converts some mass into energy, since one helium atom (weight 4.003) weighs considerably less than the four hydrogen atoms (weight 1.008 each) which build it. This reaction is very slow, requires carbon to catalyze it, and occurs only deep within the sun's mass where excessively high pressures and temperatures prevail. The postulated reactions are

$$_6C^{12} + {}_1H^1 \rightarrow {}_7N^{13} \rightarrow {}_6C^{13} + {}_1\varepsilon^0$$
$$_6C^{13} + {}_1H^1 \rightarrow {}_7N^{14}$$
$$_7N^{14} + {}_1H^1 \rightarrow {}_8O^{15} \rightarrow {}_7N^{15} + {}_1\varepsilon^0$$
$$_7N^{15} + {}_1H^1 \rightarrow {}_6C^{12} + {}_2He^4$$

where $_1\varepsilon^0$ represents a positron, a particle of positive electricity with vanishingly small mass. As remarked, these reactions are slow. Reactions which may be fast enough to be used in a hydrogen bomb produce helium from the heavy isotopes of hydrogen, namely, deuterium $_1H^2$ and tritium $_1H^3$.

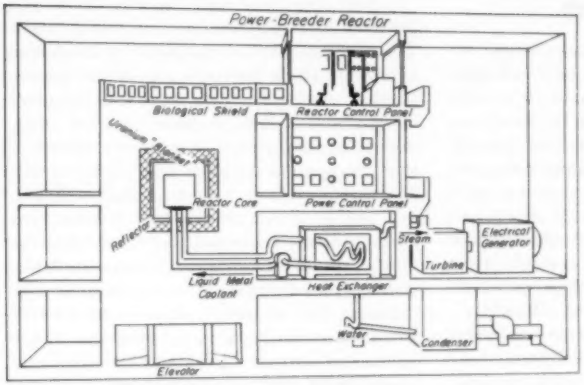

Fig. 3 — Schematic Model of Combined Power-Breeder Reactor (Courtesy Idaho Falls Operations Office). Heat generated in reactor at left is removed by circulating liquid metal, and generates steam in heat exchanger at center. This operates a condensing steam turbine which in turn drives an electric generator

Reflector — A reflector is a blanket of material surrounding the reactor to mitigate the leakage of neutrons, by reflecting or scattering as many as possible of them back into the reactor. The reflector must be composed of material which will not tend to absorb too many neutrons by parasitic capture.

Neutron Cross Sections — The interaction between neutrons and atomic nuclei of elements can be expressed in terms of nuclear cross section. The total neutron cross section of a particular nucleus is the fraction of neutrons it intercepts per square centimeter of neutron beam. The fraction of neutrons the nucleus scatters is called its scattering cross section; the fraction captured is called its absorption or capture cross section.

Moderator — A moderator is a substance which slows down or moderates fast neutrons, thus increasing their probable capture by the nuclear fuel. Moderators are generally elements that possess low atomic weight, low capture cross section, and high scattering cross section.

Control — A reactor is regarded as being under control when it can be made subcritical, critical, and overcritical by the manipulation of some mechanism such as the insertion and withdrawal of control rods to specified positions. Control rods consist essentially of materials containing elements with high capture cross sections for neutrons.

About 80% of the 200 million electron volts (200 Mev.) of energy released per fission is manifested as kinetic energy of the fission fragments. The velocity of these fragments corresponds to a temperature approximating 600 billion degrees Centigrade (if "temperature" has any meaning at such extremes), and it seems somewhat wasteful to degrade this high temperature down to a few hundred or a few thousand degrees. Considerable study has been devoted to various methods for the *direct* utilization of this energy of fission by such methods as chemical, electric, thermo-electric, and electromagnetic. However, no method seems to be practically feasible, and it has been conceded that, with the present state of the art, its conversion and removal must be done as heat at some tractable temperature.

HEAT UTILIZATION

Various conventional methods which can be considered for use in removing heat from a nuclear reactor are radiation, condensation, boiling, conduction, and convection. Let us examine each one briefly.

Radiation does not seem to be an effective means of transferring heat, either within the reactor itself or in a secondary system external to the reactor. Its main drawback is that excessive temperatures are needed for transfer of significant amounts of heat by radiation, even though radiation increases as the fourth power of the temperature. For example, a temperature of approximately 6800° F. is required in order to radiate as much heat per square foot per 100° F. temperature differential as can be conducted

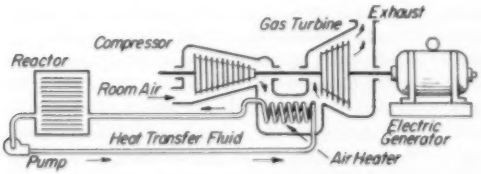

Fig. 4 — Sketch of a Possible Power Plant Using a Binary System, in Which the Heat Is Extracted From the Reactor in Closed Cycle and Utilized in a Gas (Air) Turbine in Open Cycle

through one square foot of copper or silver.

A fluid system wherein the liquid is boiled within the reactor and condensed in an external heat-absorbing unit can be an excellent method of heat transfer, but strong objections might be raised against its use within the reactor itself. Since boiling and condensation cause fluctuations in the average density of the coolant, the control problem may become severe and controls may become even inoperable. This problem must await further experimentation. However, boiling liquids and condensation methods for heat transfer should prove extremely important in the external power cycles, as they have in many conventional power plants such as the steam turbine.

Conduction and convection methods for heat transfer appear to be the most important, most practical, and simplest means of transferring heat from a nuclear reactor. By this device the heat generated by the fission process is carried away by circulation of a cooling or heat transfer medium through the reactor. The heat generated within the fuel elements themselves is brought to the surface of the elements primarily by conduction, and is then transferred to and transported away by the heat transfer medium both by conduction and convection. On emerging from the reactor, this heat transfer medium could carry its heat directly to a heat engine or indirectly through one or more heat exchangers to a secondary or tertiary medium. The general scheme is illustrated in Fig. 3.

Whether a direct or an indirect cycle can be used is dependent to a large extent upon whether the heat transfer medium becomes contaminated with radioactive products. This contamination might be due to the escape of fission fragments into the reactor coolant, radioactive products of corrosion or erosion, and induced radioactivity in the coolant itself. If protection against such radioactive contamination can be assured, a direct cycle for heat absorption and disposition becomes highly desirable. Such a cycle, for example, might be a gas turbine operating on hydrogen, superheated in the pile. If protection from radioactivity is impossible, an indirect cycle must be used. Such a cycle might consist of just one additional cooling circuit (binary system), or more than one, depending upon the particular requirements of the power plant.

Both the direct and indirect cycles can be used in either an open or closed cycle. The open cycle is the one-pass type of cooling system in which the coolant goes through the reactor, absorbs heat, transfers it to the point of application, and is then thrown away. Such a system generally requires abundant and inexpensive coolants like water or air. The closed cycle such as diagrammed in Fig. 4 is one in which the coolant is conserved by repetitive circulation, and is suitable for less plentiful and more expensive coolants. Both open and closed cycles can be used with the same nuclear power plant in order to fill a certain need. Various combinations of the direct and indirect cycles and the open and closed cycles are likewise possible.

HEAT TRANSFER MEDIUMS

The type of material required to serve as a heat transfer medium is dependent upon its nuclear and physical properties. Either gaseous or liquid compounds could be employed for this purpose.

Gaseous Coolants — Some of the relatively common gases for coolants are air, hydrogen, helium, and carbon dioxide. These gases could be used for removing the heat from any type of reactor operating at any temperature. They are particularly useful, however, for the very high-temperature reactors, since the thermal decomposition temperature of their molecules far exceeds that of practically all molten compounds — and, in fact, is higher than the maximum operating temperature level of the reactor (dictated by the limiting temperature set by the materials of construction).

The advantages of air as a coolant are manifold. It is cheap, very abundant, and its physical properties are relatively well known. It is an ideal coolant for an open cycle system, both for stationary and mobile nuclear power plants. Its main disadvantages are its poor heat transfer properties and its tendency to oxidize metals with which it comes in contact. Thus, fuel elements and moderators must be made of materials which resist oxidation by hot air, or they must be protected by suitable jacketing or cladding.

Hydrogen has very excellent heat transfer properties for a gaseous compound, and it is inert to most materials, particularly at high temperatures. (At lower temperatures, it does tend to form hydrides with various metals.) For a mobile power plant, it is

questionable whether hydrogen could be used in any but a closed cycle, although it is possible that liquefaction equipment could be made light enough so that hydrogen could be used in an open cycle for some mobile units. Two disadvantages of hydrogen would be its cost and the danger of explosion if oxygen should happen to gain entry into the cooling system.

The complete chemical inertness and the radiation stability of helium are its two chief advantages as a gaseous coolant. However, it is not cheap, not overly abundant, and must be used in a closed cycle. This would require a very heavy or large heat exchanger.

Carbon dioxide would probably be a more effective gaseous coolant for reactors operating at low or intermediate temperatures than at high temperatures. For reactors operating near the thermal decomposition temperature of CO_2, the corrosive effects might be excessive due both to thermal decomposition and irradiation effects. For a one-pass type of cooling system, the corrosive effects induced by radiation would probably be negligible, but may be much greater in a closed cycle. However, the latter type of system would probably be indicated for use with carbon dioxide as a coolant.

Liquid Coolants — Various types of compounds which are liquid either at room temperature or at higher temperature could be used as heat transfer mediums. Some of these compounds are water, heavy water, organics, molten salts, and molten metals.

Water occupies a position similar to that of air — it is cheap, very abundant, and readily accessible. Its chief disadvantage is its relatively low boiling point, which limits its use as a coolant to low-pressure reactors operating at relatively low temperatures. In order to use it at temperatures appreciably exceeding its boiling point, higher pressures must be used to suppress boiling and bubble formation, and this requires strong pipe systems and the required metal may greatly affect the reactivity and control of the reactor.

"Heavy water" (water in which the hydrogen is the isotope of mass 2, known as heavy hydrogen or deuterium) is similar to ordinary water as a liquid coolant except for a few marked differences. It is not cheap but quite expensive. It is much more desirable as a coolant because deuterium does not absorb many neutrons and this results in a fuel saving. Heavy water, in fact, is an excellent moderator.

Cooling Systems and Materials

Organics, whether of the hydrocarbon or deuterocarbon type, have several disadvantages. Their heat transfer properties would be considered quite poor in comparison with water. The boiling points, and consequently the operating temperatures at normal pressures, are considerably better for some compounds than water possesses. However, their susceptibility to radiation damage is quite marked and is a serious drawback. In addition, the deuterocarbons are quite expensive.

For reactors operating at high temperatures, molten salts may be suitable coolants. Their main disadvantage is that salt mixtures composed of elements with acceptable nuclear properties have high freezing points. Such a coolant would have to be maintained at a temperature above its freezing point or adequate design incorporated in the system so that the coolant could be melted during start-up. Obviously, molten salts are limited to a closed cycle system.

Molten metals as a general class have the same disadvantages as molten salts. Some of the molten metals that could be used are mercury, lead, bismuth, lead-bismuth eutectic, sodium, potassium, and sodium-potassium eutectic. All of these materials except mercury and sodium-potassium eutectic are solid at room temperature.

Power plant engineers already have some operating experience with a mercury boiler. Mercury could conceivably be used in an open cycle, the mercury not being thrown away but recondensed in a separate system. However, the nuclear properties of mercury are quite unacceptable. It has a high capture cross section for thermal neutrons and could not be used in either thermal reactors or in many fast reactors.

With the possible exception of mercury, the molten metals would be restricted to a closed cycle. Some of the problems involved in such equipment are corrosion, purification, handling techniques from a contamination viewpoint, and inflammability in air. Generally speaking, their heat transfer properties are good — better than those of any other suggested type of coolant.*

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*EDITOR'S FOOTNOTE — A considerable volume of data on thermal properties and corrodibility of liquid metals has been published in "Liquid Metals Handbook", Office of Naval Research, Publication NAVEXOS P-733. See *Metal Progress* data sheets for December 1950 and January 1951.

Different Kinds of Reactors

As is apparent, a nuclear reactor is, in the simplest sense, a controlled chain reaction. The fission process takes place in the nuclear fuel which may be natural uranium, one of its fissionable isotopes, plutonium, or various mixtures thereof (generally termed "enriched uranium").

The heat from the fission process is carried off by some such vehicle as water or air. The energy may then be transferred into electrical energy or propulsive energy, depending upon the particular engineering application.

An interesting fact about reactors is that any amount of power from a few watts to many thousands of kilowatts can be produced from almost any size of reactor! In a small power-producing reactor, the limitations on the extraction of energy would be from thermodynamics and engineering. We would obviously want to spread our nuclear fuel over a sufficiently large volume so that the energy liberated could be extracted.

Nuclear reactors may be classified in several different ways. Clark Goodman, in his book "Science and Engineering of Nuclear Power" (Addison-Wesley Press, Cambridge, Mass., 1947), divides them into two general classes with three types under each class. The two classes are "homogeneous" and "heterogeneous"; this classification identifies the reactor from a compositional and structural basis. The three reactor types for each class are thermal, resonance or epithermal, and fast. Six designs may therefore be considered.

A homogeneous reactor is one in which the fissionable material is uniformly distributed in a moderator. An example of this type is the Los Alamos water boiler (Fig. 5 and 6) wherein the fissionable material (U^{235}) is dispersed as uranyl nitrate in ordinary water. A heterogeneous reactor is one in which the fissionable material is introduced into the reactor independent of the moderator, such as the first pile constructed at the University of Chicago in the West Stands of Stagg Field (Fig. 1). Graphite was the moderator, and natural uranium and its oxide formed the fissionable material.

The three reactor *types* derive their names from the energy of the neutron which produces fission. In the thermal reactor, it is necessary to degrade the energy of the fast neutrons (about 1,000,000 electron volts, or 1 Mev.) resulting from fission to about 0.02 electron volts to maintain the chain reaction. This requires that additional foreign material be present in the reactor to thermalize or moderate the neutrons. Materials most efficient for neutron moderation are those containing beryllium, carbon, hydrogen, or deuterium. Such reactors are usually the largest of the three types. Examples of this type of reactor are the Oak Ridge National Laboratory graphite reactor, designed and built early in 1943 and operating at about 1000-kw. power level, and from which engineering data were secured for the very much larger piles at Hanford, Wash., designed primarily, of course, for the manufacture and recovery of plutonium.

A resonance or epithermal type of reactor is one in which the energy of the neutrons producing fission is somewhere between thermal (about 0.02 electron volts) and fast (about 1 Mev.). Such reactors will operate at an intermediate energy level and are usually, but not always, somewhat smaller than thermal reactors (Fig. 7).

A fast reactor is one in which the energy of the neutron causing fission is very near fission energy. This is the smallest type of reactor and requires no moderation. An example of this type of reactor is the first atom bomb that was exploded over Hiroshima on Aug. 6, 1945.

So far, reactors have been classified on

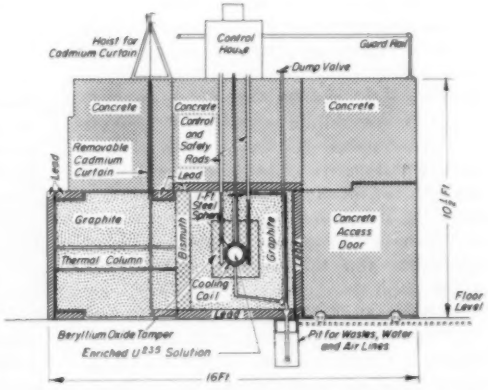


Fig. 5 — Schematic Drawing of Los Alamos Homogeneous Reactor ("Water Boiler"). Reactor is a 12-in. sphere containing U^{235} nitrate solution. Reflectors (tampers) are beryllium oxide and graphite. Shielding is of cadmium sheet to absorb slow neutrons, concrete for fast ones, and lead for gamma radiation. Control rods enter the beryllium oxide tamper rather than the reactor itself. (Courtesy of U. S. Atomic Energy Commission)

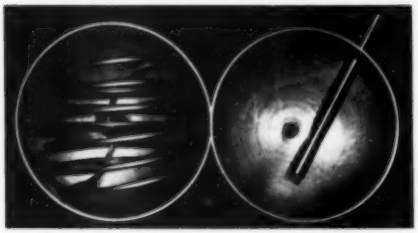


Fig. 6 — Two Halves of Spherical Container for Uranium Solution of Los Alamos Homogeneous Reactor. Coil is also of stainless steel, for cooling water. Loose pipe at left is welded in holes through sphere, and is a port for placing experimental materials in region of highest neutron flux. (Courtesy Los Alamos Laboratory)

a class and type basis with no reference to their fuels. Reactor fuels are those materials which have a high probability of fissioning when their nucleus is struck by a neutron. There are two types of reactor fuels which for simplicity can be called primary and secondary. The primary fuels are natural uranium (99.3% U^{238} plus 0.7% U^{235}) and the separated isotope U^{235}. The secondary fuels

Primary and Secondary Reactor Fuels

are plutonium and U^{233}. By definition, primary fuels are those that exist in nature; secondary fuels are those that are produced artificially.

When the nucleus of $_{92}U^{238}$ captures a neutron ($_0n^1$) it forms unstable $_{92}U^{239}$, which by beta decay (acquisition of two positive charges on the nucleus) results in the formation of plutonium $_{94}Pu^{239}$. The intermediate decay products between uranium 238 and plutonium 239 are the isotopes $_{92}U^{239}$ with a half life of 23 min., and neptunium $_{93}Np^{239}$ with a half life of 2.3 days. Similarly, when a thorium $_{90}Th^{232}$ nucleus is struck by a neutron, it is converted by natural radioactive beta decay to uranium 233.

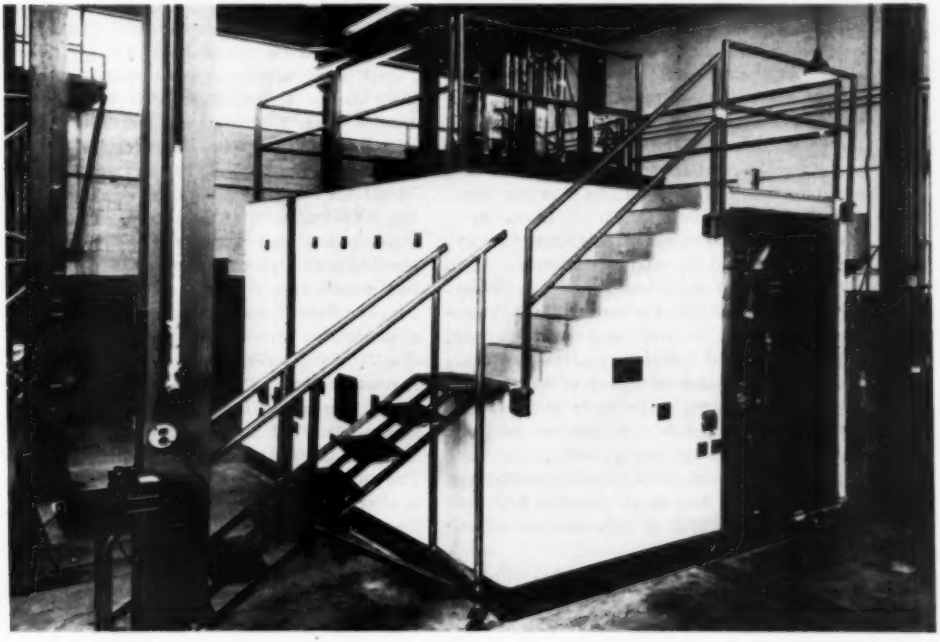
Equations expressing these reactions are as follows:

$$92U^{238} + 0n^1 \rightarrow 92U^{239} \xrightarrow[23\ Min.]{\beta^-} 93Np^{239} \xrightarrow[2.3\ Days]{\beta^-} 94Pu^{239}$$

$$90Th^{232} + 0n^1 \rightarrow 90Th^{233} \xrightarrow[23.5\ Min.]{\beta^-} 91Pa^{233} \xrightarrow[27.3\ Days]{\beta^-} 92U^{233}$$

From these equations, we see that it is possible to produce fissionable materials from

Fig. 7 — Exterior View of Epithermal Type of Reactor, Nicknamed "Clementine" at Los Alamos Scientific Laboratory



nonfissionable ones by exposing them to a neutron flux.

In the fissioning of a uranium 235 nucleus with a thermal neutron, almost exactly 2½ neutrons are emitted, on the average. If only one neutron is required per fission to keep the chain reaction going, the others could be captured by uranium 238 or thorium to produce additional fissionable material. If the process were highly efficient — no neutrons lost to the outside or absorbed in side reactions — more new fissionable material would be created than is consumed! This is the basic principle of the breeder reactor. It uses fissionable material to sustain a chain reaction, and produces a secondary nuclear fuel as a byproduct. An experimental reactor of this type (Fig. 2 and 3) has recently been constructed at Arco, Idaho, by the Atomic Energy Commission.

A schematic model of a nuclear power plant is shown in Fig. 3, and gives the general components of the system. The fuel used is a uranium compound in solution, but it could also be uranium metal in rod form which is inserted into a moderator structure. Figure 3 indicates a homogeneous reactor; the other would be a heterogeneous reactor. The nuclear reactor is cooled by liquid metal that is passed through a boiler or heat exchanger to generate steam. This steam, in turn, is fed to the steam turbine which drives an electrical generator. The steam is condensed and pumped back through the boiler to repeat the cycle.

EDITOR'S ADDENDUM — It may be of interest to compile a list of the reactors now operating. The data are from Glasstone's "Sourcebook", reports of U. S. Atomic Energy Commission, and the engineering press:

The original reactor built under the West Stand at Stagg Field, University of Chicago, was dismantled in 1943 and re-erected at Argonne National Laboratory at Palos Park, Ill. About 10 tons of uranium metal and 40 tons of uranium as oxide form the fuel. Moderator is graphite. It has no cooling system and can run only at low power, up to 100 watts (about as much as consumed by one light bulb) for short periods, and its consumption of U^{235} at this rate is about 0.001 g. per day.

The next reactor, the air-cooled Clinton pile, was completed at Oak Ridge, Tenn., on Nov. 4, 1943. It was a pilot plant for producing plutonium, and designed to operate at 1000-kw. power level, but can operate continuously at more than double that figure. The metallic uranium rods in this pile are aluminum-clad and lined up loosely in channels so they can be air cooled and also ejected through doors in the back-wall when fresh uranium rods are introduced.

The three large plutonium-producing piles at Hanford are water cooled, fueled by natural uranium and moderated by graphite. Operation of the first started on June 7, 1943, and the wartime installation has since been largely increased (possibly doubled).

The British have two experimental piles at Harwell. The first and larger is called BEPO (British Experimental Pile O). It started operation in mid-1948. It is a graphite-moderated, air-cooled pile requiring 28 tons of uranium to reach criticality and is actually loaded with about 40 tons. Air cooling limits the temperature of the fuel elements to 200° C. when operating at a power level of 4000 kw.

The British "Gleep" (graphite low-energy experimental pile) at Harwell is a slow neutron reactor, moderated with graphite, designed to run at as high a power as possible without an elaborate cooling system. The fuel-moderator system is a rough cylinder, about 9 ft. 4 in. radius and 17 ft. long. The core is stocked with 12 tons of uranium metal, the peripheral region with 21 tons of UO_2. It can be run at about 100-kw. level.

Of the postwar graphite-moderated piles built in the United States, the Brookhaven reactor (Fig. 9) was completed in 1950 and is notable in size. It is exclusively for research, and can operate at any level up to 30,000 kw. Its air cooling system requires five 1500-hp. motors. Provision is made so some power can eventually be generated, providing enough to run some of the auxiliary machinery.

The first reactor using heavy water as a moderator and natural uranium as fuel (Fig. 10) was operated at Argonne National Laboratory in May 1944. Known as CP-3, its normal operating level was 250 kw., and it was cooled by circulating the moderator through an external refrigerating system. The tank holding the 6½ tons of heavy water is about 7 ft. in diameter and 8 ft. tall; into it are hung about 120 uranium rods weighing hardly 3 tons. It is now being dismantled and will be replaced by a much larger reactor (CP-5) of the same type, except that the natural uranium will be enriched by add-

ing the $_{92}U^{235}$ isotope, and so produce high neutron densities.

Canada has two heavy-water moderated reactors at Chalk River, Ont. The first, known as "ZEEP" (zero energy experimental pile), is similar in design to the CP-3 reactor described in the last paragraph. It was completed in September 1945, and normally operates at 3.5 watts, but this can be increased to 50 watts for short periods. The second Canadian reactor, in operation about two years, is much larger and is reputed to be most advanced in design and construction. It has been stated that the fuel is 168 rods of uranium, protected by aluminum jackets, and the heavy-water moderator is contained in an 8 x 10-ft. tank. Power level is 10,000 kw.

Another of these reactors using heavy water for moderator began operating Dec. 15, 1948, at Saclay, France. (See *Metal Progress*, August 1949, p. 202, for details.) It is nicknamed "Zoé" (zéro, oxyde d'urane, eau lourde). Fuel is sintered rods of purified UO_2. This 10-kw. pile contains perhaps 30 tons of uranium metal as oxide; the power level is limited by the requirement that the moderator must be kept at such low temperature that evaporation is negligible.

A similar reactor is reported to be under cooperative construction by the governments of Norway and Belgium.

A shield testing reactor at Oak Ridge uses movable fuel elements mounted in an aluminum grid, immersed in a very large tank of water. Its full-power rating is 10 kw.

A research reactor at Los Alamos Scientific Laboratory in New Mexico is called the "water boiler" or HYPO (see Fig. 5 and 6). It started in December 1944. The fuel is a soluble salt of uranium, such as the sulphate or nitrate, and the moderator is ordinary water. It is a homogeneous reactor, and operates at 185° F., a power level of about 6 kw. Its cost is much less than the large heterogeneous reactors. One of similar size is under construction at North Carolina State College. A much larger homogeneous reactor of undisclosed characteristics is now nearing completion at Oak Ridge National Laboratory. It will ultimately operate a small turbo-generator.

The other small Los Alamos reactor ("Clementine", shown in Fig. 7) operates on $_{94}Pu^{239}$ without a moderator. It is of the epithermal type — that is, operates on fast neutrons — and is essentially a controlled atomic bomb. It is cooled by mercury.

Reactors Under Construction

A much larger experimental breeder reactor is in operation at Arco, Idaho (Fig. 3), similar to "Clementine" at Los Alamos; it operates with fast neutrons, has no moderators, and is cooled with liquid metal. It generated useful power for the first time on Dec. 20, 1951, at the rate of 100 kw.

A second reactor at this testing station in Idaho is the materials testing reactor (MTR) for testing materials of construction under a high flux of thermal neutrons. It became critical on March 31, 1952. The fuel is enriched uranium in units designed for rapid heat transfer. Coolant is water, circulating at high velocity. It cost about $18,000,000.

Reactor CP-6 is now under construction at the Savannah River site in Georgia, probably for the manufacture of tritium, $_1H^3$.

A land-based prototype of a submarine thermal reactor power plant is under construction by Westinghouse Electric Corp., and the U. S. Navy has contracted for the hull with Electric Boat Co. General Electric Co. is developing a land-based prototype known as "SIR" (submarine intermediate reactor) and will use neutrons of intermediate range (epithermal).

Aircraft units are being studied by the General Electric Co. and Pratt & Whitney with supporting work on the airframe by Consolidated Vultee Aircraft Corp. and Boeing Airplane Co.

Details of reactors mentioned in the last four paragraphs have not been disclosed.

OPERATION AND CONTROL

Operation and control of nuclear power plants involve two major phases: *(a)* Operation and control of the reactor itself, and *(b)* the operation and control of the power plant as a whole.

Reactor Control — The amount of heat generated in a reactor is dependent upon the frequency of the fission process, which is itself dependent upon the neutron density. Thus, by regulating the neutron density, the heat generated per unit time can be controlled at a level concomitant with the means available to remove this heat for either useful power or for dissipation. The neutron density itself can be varied by changing the amount of fissionable material for absorbing the neutrons, by changing the amount of

Methods for Reactor Control

material acting as parasitic absorbers of neutrons, and by regulating leakage of neutrons from the reactor.

A rather intricate engineering design involving mechanical ingenuity would be necessary to control a heterogeneous reactor by changing the amount of its fissionable material. In any event, the nuclear fuel needs to be arranged so that it can be readily removed and replaced when it becomes poisoned by reaction products.

Thermal and epithermal reactors can usually be somewhat readily controlled by incorporating parasitic absorbers of neutrons into the system. The materials used — for example, boron and cadmium in various forms — all have high cross sections for the capture and absorption of neutrons. Such parasitic absorbing mediums may have to be cooled, due to the large heat release resulting from high neutron absorption.

The number of neutrons leaking from a reactor can be minimized by the use of a reflector, by arranging the reactor in a fixed geometric configuration, and by using a definite amount of moderator in the reactor. Hence, the leakage can be varied by moving the reflector, by changing the surface-volume ratio of the reactor, and by changing the amount of moderator in the reactor.

Can all these methods of control be incorporated into a single mechanism? This is possible, but it is not too attractive for heat sources for nuclear power plants, since power levels of hundreds and thousands of kilowatts may be involved. Even so, as applied to each of these general methods, two or more types of controls are required.

Three types of reactor control are *(a)* coarse or gross power adjustments, *(b)* fine or small power adjustments, and *(c)* emergency or "scram" control. The coarse control will bring the reactor up to the operating power level; large or gross changes in the operating level can also be handled, and the reactor can be shut down. The fine control can be used for making the small adjustments required over long periods of time to maintain exactly the operating level to which the reactor has been brought by the coarse control. The emergency or scram control is designed to serve as a safety control, capable of stopping the chain reaction fast enough to counteract any major tendency of the reactor toward self-destruction.

Over-All Control of Nuclear Power Plant — Incorporation of a nuclear reactor as a heat source into a power plant does not generally change its specific controls, but over-all control of the integrated power plant as one unit then becomes of paramount importance. For purposes of discussion, the power plant can be considered as consisting of a compressor, a heat exchanger, a nuclear reactor serving as the heat source, and a turbine serving as the heat engine (Fig. 8a).

A nuclear reactor can be designed to operate under very low stresses with a minimum of moving parts, whereas a turbine is a high-speed machine with high-stressed moving parts such as the turbine blades and turbine wheel. The safe stresses are functions of the speed and temperature of the turbine. Since turbine materials frequently operate near their limits at their full rated speed, it is apparent that some means of control must be afforded to prevent overspeeds or overtemperatures for even short periods of time. This could be accomplished by allowing both turbine speed and turbine temperature to operate the controls either by regulating the inlet gas temperature to the turbine, or by checking overspeeding.

If the power plant does not demand quick changes in power level, the inlet gas

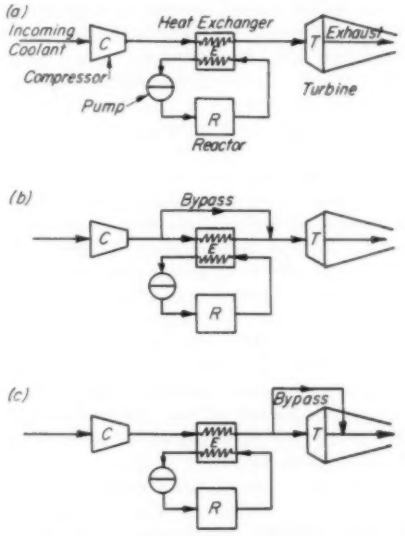


Fig. 8 — Three Methods for Control of Nuclear Power Plants Using a Binary System With Closed and Open Cycles.

temperature to the turbine might be regulated by varying the power output of the reactor. Frequently, however, the reactor, being closely controlled itself, will be too sluggish for prompt reply to the demand on the electric system.

One simple method of control which might be employed is illustrated in Fig. 8b, wherein a bypass line could be used to channel a controlled amount of cold air issuing from the compressor directly into the hot gas stream coming from the heat exchanger. In this manner, the reactor and heat exchanger could be run at temperatures far exceeding safe operating temperatures for the gas turbine, since the gas leaving the heat exchanger can be cooled considerably by such dilution before it enters the turbine. Similarly, for propulsion purposes the hot gas issuing from the heat exchanger could be cooled by channeling a portion of it directly to the turbine exhaust as illustrated in Fig. 8c.

Other similar methods of control could be cited, and various combinations have been suggested by L. A. Ohlinger in *Nucleonics* for March 1950. General methods for overall control of a plant which includes a turbine operating at high temperature should probably be based on the speed and temperature of the turbine and not upon the varying power output of the reactor.

MATERIALS OF CONSTRUCTION

The materials of construction for nuclear reactors must be specified in a unique manner, as one must consider factors which are of no concern to equipment and machinery outside the atomic energy field. Nuclear properties of materials are just as important as the chemical analysis of a heat of steel or its mechanical properties.

The usual nuclear specification deals with the absorption cross section (parasitic capture) for neutrons. The numerical specification of the cross section is expressed in "barns" (1 barn = 10^{-24} sq.cm. per nucleus). For example, the absorption cross sections of thermal neutrons at 0.025 electron volts for the various elements going into the usual high-temperature alloys are given in the table at the bottom of the opposite column.* Clearly, iron presents a much smaller area for absorption of neutrons and, consequently, would be more desirable than cobalt for the reactor core, and a silicon-iron would be

preferable for high-temperature service over a chromium-iron.

From the standpoint of thermal neutron capture the light metals are very attractive (Be 0.01, Mg 0.07, Al 0.22) and the other nonferrous metals except copper are distinctly superior to iron and its ordinary alloys:

Lead	0.18	Zinc	1.0
Zirconium	0.4	Strontium	1.3
Tin	0.6	Copper	3.6

Such limitations are not of serious concern if the reactor is planned to operate at low temperatures where iron may be used. If it is desired to operate at high temperature, it is necessary to consider the use of high-temperature alloys. The principal "superalloys" now contain cobalt and tungsten, both very undesirable in nuclear reactors. Nickel, another common addition element, has a cross section of 4.5 barns at 0.025 electron volts. This limitation of the selection of materials can have a profound effect on the future of high-temperature reactors and means that new materials which do not contain objectionable elements nuclearly must be developed. This is particularly true of thermal reactors.

For epithermal reactors, this may not be as serious, as the cross sections usually decrease with increasing energies. However, it must be remembered that reactors generally become smaller as the energy of the neutrons causing fission increases, and then the amount of power which can be extracted from a given volume may prove to be the limiting factor. The requirement of the development of materials of low cross section would strongly suggest a study of nonmetallics or metal-ceramic combinations; to achieve this end the nuclear metallurgist is therefore working in the same direction as his professional brothers in the jet engine fields in their search for turbine blade materials to operate up to 3000° F.

One then approaches the specification of material for a nuclear reactor from the standpoint of its chemical, mechanical, phys-

*Absorption cross sections from General Electric Research Laboratory "Chart of the Nuclides", Dec. 1949.

Iron	2.4 barns	Silicon	0.1 barn
Nickel	4.5	Columbium	1.2
Chromium	2.9	Titanium	5.8
Vanadium	4.8	Cobalt	35
Molybdenum	2.4	Tungsten	18
Manganese	12.0		

Extractive Metallurgy of Uranium

ical and nuclear properties. For ease of discussion, we may divide a nuclear reactor into three principal parts as follows:

1. Reactor core materials
   (a) Nuclear fuel
   (b) Moderator
   (c) Coolants
2. Shielding materials
   (a) Reflector
   (b) Neutron shield
   (c) Gamma shield
3. Structural materials

The fuel materials have been mentioned previously. These are natural uranium (a mixture of isotopes), isotopic uranium 235, isotopic uranium 233 and plutonium. Uranium has a low melting point (2060° F.) and is, consequently, of limited usefulness for high-temperature reactors. Uranium oxide or uranium carbide could therefore be considered as the fuel which would permit considerably higher operational temperatures.*

The fabrication of uranium dioxide or uranium carbide into fuel blocks would be a difficult problem. These materials are hard and, consequently, difficult to machine. Grinding probably would be necessary to make fuel blocks to dimensional tolerances, and this would be a slow and expensive process. One can conceive of mixing the pulverized fuel with a moderator such as graphite, but the fabrication and final machining might not be any easier.

The moderator of the reactor, as previously pointed out, must slow down or moderate the neutrons, fast as born, to thermal energies. Choice rests between water, heavy water, carbon, and beryllium. For low-temperature reactors, one may select an

*Editor's Footnote — A brief account of the extractive metallurgy of uranium was given by Frank G. Foote, director of the metallurgical division of Argonne National Laboratory, in a talk before the Notre Dame Chapter ⊖, on April 9, 1952, from which the following is taken.

Prior to the start of the nuclear energy program, uranium was a relatively unknown and but little used element. Considerable quantities of uranium-bearing ores had been mined but were worked for their radium or vanadium content, the uranium being a practically useless waste. From the standpoint of the nuclear energy program this was a rather fortunate circumstance, since there was a considerable stockpile of uranium-bearing material above ground and available for processing.

Uranium compounds are difficult to reduce and any reducing agent sufficiently powerful to free the metal will also reduce practically all the other minerals in the ore to free metal. Further, it is virtually impossible to remove impurities from uranium metal once they are introduced. Refining methods such as selective oxidation, volatilization or electrolysis commonly used to refine many of our more common metals therefore cannot be applied to uranium. It is necessary to remove the impurities prior to reduction to metal, and highly successful and only moderately complicated processes have been devised for this purpose. The reduction plant is therefore furnished a highly purified concentrate of raw material; it is the smelter's job to produce metal without introducing any additional impurities of his own.

At the beginning of the atomic bomb project, two reduction methods were available and had been used to produce small quantities of metallic uranium. Both were expanded to rather large-scale production.

An electrolytic process had been developed by Driggs and Lilliendahl of Westinghouse Electric Corp. This process (described at some length in *Metal Progress* for April 1948, p. 519) consisted in the electrolysis of potassium-uranium fluoride (KUF_5) in a fused mixture of sodium and calcium chlorides. The KUF_5 was produced by the photochemical reduction of uranyl nitrate with formic acid — a photosynthesis carried out in tubs on the roof, and cloudy days would seriously hold up production. It was later found that uranium tetrafluoride (UF_4) prepared by the hydrofluorination of the oxide could be used instead of the KUF_5 and the operation was thus freed of dependence upon the weather.

Electrolysis was carried out in graphite crucibles at 1475° F. with molybdenum strip anodes. The uranium was deposited as a loosely adherent mass admixed with the electrolyte. The electrode was withdrawn and cooled, the deposit chipped off, crushed, washed with water, wet ground, again washed, filtered, and dried. The coarse metallic powder thus obtained was then pressed into pellets and fused in vacuum in beryllia crucibles using high-frequency induction heating. A product analyzing 99.9% was made, most of the remainder being Fe, Si, and C. During January 1943 this process was producing an average of 500 lb. per day and a total of 65 tons was produced before it was discontinued.

A second process was the hydride process developed by P. P. Alexander and operated by the Metal Hydrides Corp. (*Metals and Alloys*, Vol. 9, 1938, p. 270). In this process, calcined uranium oxide and powdered calcium hydride are thoroughly mixed and loaded into open steel containers, and heated to about 1830° F. in a special hydrogen furnace. The hydride decomposes gradually and the resulting hydrogen and calcium reduce the uranium oxide to metal. The product is a clinker of metal powder and lime. The mass is broken up, the lime leached out and the uranium powder washed and dried. The final powder is quite fine — 150 to 300 mesh — and somewhat pyrophoric. It can be pressed into briquets or melted in a vacuum furnace.

As noted in the "Smyth Report", both of these were later replaced by a new process developed by F. H. Spedding and associates at Iowa State College. This new process is simple, rapid and low in cost, but details are still secret.

The published melting point of uranium has fallen steadily through

inexpensive moderator such as ordinary water. In a high-temperature reactor, the choice is not quite so simple. Carbon or graphite would be a logical choice, if it were not exposed to oxidizing conditions and large stresses.* Beryllium oxide or beryllium carbide could be used as moderators for very high temperature. The fabrication technology of beryllium oxide is fairly well developed. The problem of producing pieces to exact dimensions is none too different from that mentioned previously for uranium oxide. Beryllium carbide would probably be quite similar in this respect, but very little is known about this material.

Among the possible coolants, water, heavy water, and air have been reported in use. One could also consider the use of helium, carbon dioxide, sulphur dioxide, and low-melting point metals with low cross sections. Among the fusible metals with absorption cross sections less than 1.0 are sodium, magnesium, aluminum, zinc, rubidium, lead, and bismuth. In the case of water, the coolant could act both as moderator and coolant. In the case of the gases or liquid metals, they would only serve as heat transfer media. A reactor cooled with a gas or liquid metal would require a separate moderator, and rather severe corrosion problems would probably have to be met.

If we consider the reflector as a part of the protective shield, it must serve the function of returning the neutrons that escape from the reactor so they will not be lost to the fission process. Such a reflector material must have a low absorption cross section for neutrons and be capable of scattering them back into the reactor. Among such materials are the following:

Element	Absorption Cross Section	Scattering Cross Section
Hydrogen ($_1H^1$)	0.32	4.6
Deuterium ($_1H^2$)	0.00065	5.3
Beryllium	0.0085	6.1
Carbon	0.0045	4.8
Oxygen	0.01	4.1
Zirconium	0.4	8.0
Tin	0.6	4.0

For low-temperature application, there is ample choice. Common reflectors consist of one or more of the moderating elements just listed, but if these elements were considered for high-temperature service, it would be necessary to resort to their infusible compounds with the attendant problems mentioned previously. Zirconium and tin would probably be satisfactory for low-temperature reactors. However, one could also consider the use of ordinary water, which is more readily available and considerably cheaper than either of the others.

For elevated temperature service, zirconium dioxide might conceivably be used. It would not be as effective as beryllium oxide; however, its fabrication technology is somewhat better known.

For epithermal reactors, materials which have high cross sections at thermal energies may be considered for use as the neutron

the years, from 3075° F. (1690° C.) to about 2060° F. (1130° C.). This is a fortunate circumstance since it is obviously a great deal easier to melt and cast a metal melting at 2060° F. than one melting at 3075° F. Because of the ease of oxidation, all workers agree that vacuum melting is essential. Again, because of its chemical activity, highly refractory crucibles, such as thoria and beryllia, are used.

Despite its orthorhombic crystal lattice, no great difficulty is had in either hot or cold working the metal by conventional means.

Uranium metal reacts readily, when heated, with air or water, so some sort of protective jacket is required for the slugs used in a reactor. The choice of material was limited by nuclear physics considerations; none of the better known corrosion resistant materials such as stainless steel, nickel, or Monel metal could be used because of their high absorption of neutrons. Seven possible materials (Pb, Bi, Be, Al, Mg, Zn, Sn) of low neutron absorption cross section were available. Of these, aluminum appeared to be the best bet, both from the standpoint of availability and resistance to air and water corrosion. This appears to have been a happy choice since no serious difficulties due to corrosion of aluminum have been encountered. Aluminum "canning" is done by techniques not yet publicly divulged. In *The Engineer* for Dec. 15, 1950, p. 587, it is stated that the uranium rods used in the British low-energy experimental pile (nicknamed "Gleep"; see page 106) are 0.9 in. diameter, 12 in. long, and "sprayed with aluminum of 0.003-in. thickness to prevent the escape of recoil fission products".

*Editor's Footnote — Extreme care must be taken in preparation and handling of graphite blocks for moderators to prevent contamination. For example, in constructing the Brookhaven reactor the machinists and erectors were required to wear gloves, overalls and basketball shoes laundered each day with borax-free soap (since boron with its coefficient of absorption for thermal neutrons of 715 is a virulent "poison"). Gloves were changed hourly.

Since no bonding material is permitted and the moderator must carry some loads due to thermal changes and external forces from the cooling system, the blocks must be carefully keyed together. About 60,000 blocks were required, of 2600 different sizes and shapes, each requiring its own drawing. Dimensions were held to within a few thousandths of an inch.

reflector, since the absorption cross sections generally decrease at higher energies varying inversely as the velocity.

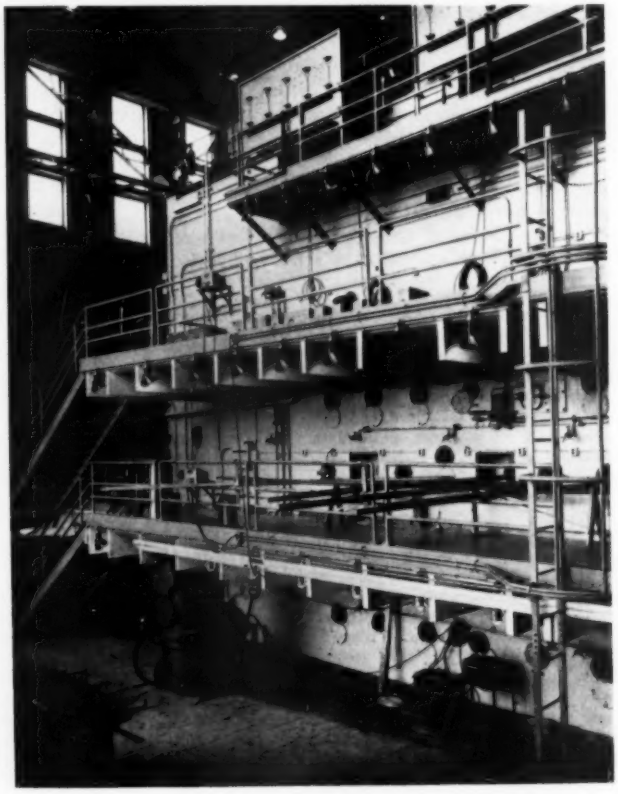
The neutrons which escape the reflector must be attenuated in the reactor shielding to a biologically safe level. The neutrons at the reflector surface will be at many different energy levels, and since thermal neutrons are more easily captured, one method would be to thermalize the neutrons in a moderator and allow them to be absorbed in a material with a high absorption cross section placed just behind the moderator. This is indicated in Fig. 5 of the Los Alamos "water boiler", where escaping neutrons are thermalized by several feet of beryllia and graphite and then absorbed by a sheet of cadmium, an element whose neutron cross section is about 3000. An alternative method would be a hydrogenous substance mixed with a high absorption cross section material in order to capture the neutrons. For example, water may be used as the moderator, and a water-soluble salt of boron, lithium or cadmium as the neutron absorber. The capture of a neutron by an absorber will often result in the emission of a gamma ray.

The gamma shield must absorb the gamma rays that are produced in the reactor or by absorption of neutrons in the structure. The gamma shield must attenuate the gamma radiation to a safe biological level, generally accepted as 0.3 roentgen unit per week. Materials which have been used to attenuate gamma radiation are the heavy elements, which have high inelastic scattering cross sections and also large absorption cross sections for neutrons. Lead and tungsten are two examples. Concrete may also be used with less efficiency on a volume basis, but it is satisfactory for stationary reactors.*

Structural materials must also be selected on a nuclear basis so long as they lie within the reflector shield. For low-temperature reactors, structural materials such as beryllium, aluminum, magnesium, and zirconium could be used. These materials would have very little high-temperature application unless they could be kept cool; this, in turn, would create a corrosion problem regardless of the coolant used unless it were an inert gas.

The materials of construction for reactors

Fig. 9 — Face of the Nuclear Reactor at the Brookhaven National Laboratory With Openings at Various Levels for Experimental Purposes.



*Editor's Footnote — An unusual use of surplus armor plate is noted in the description of the Nuclear Reactor at Brookhaven. This was designed primarily for scientific experimentation, but also provision was made to develop some power to drive auxiliary equipment. According to the British publication *The Engineer* (Aug. 24, 1951, p. 238) it can operate at any level up to 30,000 kw. capacity, and is a conventional uranium-graphite pile, air cooled. The outer shield is of armor plate, 9 to 18 in. thick, machined in 10-ton sections by the N. Y. Naval Shipyard. Joints are grooved or tenoned to avoid direct paths of energy escape and are welded around all edges.

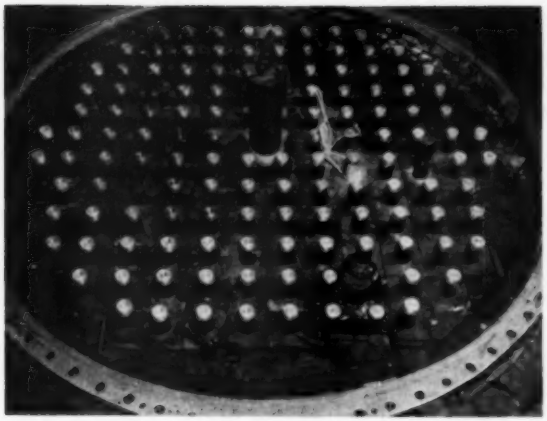


Fig. 10 — Top of Reactor Core of Argonne National Laboratory's Heavy Water Reactor. Upper shield has been removed, to show tops of uranium rods suspended in water tank, and thimbles into which materials are placed for irradiation

are very closely associated with the nuclear characteristics of the reactor. For thermal reactors, one finds that there is very little latitude in the selection of materials and a limited number of materials to choose from. The use of materials with higher cross sections in a thermal reactor means that additional uranium must be added to overcome the effects of the parasitic substance added, which, in effect, increases the uranium required to sustain the chain reaction. This is true whether the reactor be thermal, epithermal, or fast. Consequently, the specifications of materials must be weighed against the increase in critical mass required to sustain the chain reaction.

RADIO TOXICOLOGY

There are essentially two problems connected with radio toxicology. The first concerns itself with the protection and safeguarding of the operating crew and any bystanders during the useful life of the reactor. The second involves the disposition of the radioactive waste during periodic clean-up and of wastes remaining upon termination of the operating life of the reactor.

A nuclear reactor generates radiation which is very dangerous to human life. Adequate provision must be made to protect not only the operating crew but anyone who might come within its sphere of influence. Obviously, adequate shielding of the reactor must be based on some radiation limit which has been previously established. Not only must adequate shielding be provided but sufficient monitoring instrumentation must be incorporated into the reactor system so that any radiation exceeding the maximum permissible exposure can be immediately detected. Personnel within the environs of the reactor must also wear film badges and small exposure meters so that an integrated record of their exposure can be recorded.

The level of maximum permissible exposure to external sources of radiation was presented by K. Z. Morgan at the Symposium on the Role of Engineering in Nuclear Energy Development, held at Oak Ridge National Laboratory, Aug. 27 to Sept. 7, 1951. This level, shown in Table I, is based upon the maximum permissible tissue dose limits in

Table I — Maximum Permissible Dose Levels of Radiation

Type of Radiation	Any Point Within the Body*	Relative Biological Effectiveness	In Basal Layer of Epidermis	
			Exposure of Entire Body*	Exposure of Hands Only*
X-rays and gamma rays	0.3	1	0.5	1.5
Beta rays	0.3	1	0.5	1.5
Protons	0.03	10	0.05	0.15
Alpha rays	0.015	20	0.025	0.075
Fast neutrons	0.03	10	0.05	0.15
Thermal neutrons	0.06†	5†	0.1†	0.3†

*Reps per week.

†The relative biological effectiveness (RBE) and roentgen equivalent physical (Rep) values used for thermal neutrons are only approximate and have questionable meaning. Although presenting difficulties from a practical viewpoint, a thermal neutron beam can be readily analyzed theoretically by using target materials consisting of elements present in human tissue and by measuring the resulting proton recoil and gamma ray emission. The fluxes (number of particles per sq.cm. per sec.) of the proton and gamma radiations can be treated separately and their individual contributions added after weighting them properly.

The Radioactive Waste Problem

"Reps" per week ("Rep" means "Roentgen equivalent physical") agreed upon at the Chalk River Conference in September 1949, and subscribed to by the Harwell Conference in July 1950.

The disposition of radioactive waste after the operating life of the reactor is terminated is a somewhat distinct problem from that of protecting and safeguarding personnel within the environs of the reactor during operation. A nuclear reactor can be operated for only a finite period before it is necessary for the nuclear fuel to be reprocessed and freed from the fission fragments which poison the action by parasitic absorption of neutrons and reduce the efficiency of the chain reaction. During removal and replacement of the nuclear fuel (or disassembly of the reactor) extreme care must be taken to safeguard all personnel, and the work must be done by remote handling devices (robots). Design and construction of such facilities will tax the ingenuity of any group of engineers.

Until the fuel and the fission fragments are separated, the mixture is very radioactive and must be handled in specially designed facilities. After efficient separation, the purified fuel is ready for reprocessing to any desirable form by conventional means. However, the separated fission fragments are very radioactive and constitute what is ordinarily termed radioactive waste, and their disposition may some day become one of the most pressing problems of this country. Burial involves the isolation of large land areas; even larger areas will be required as more nuclear power plants come into being. Dissipation of wastes into large bodies of water, even the ocean, must be balanced against their destruction or damage to marine life, fish and flora, with possible subsequent poisoning of humans. As with other waste disposal problems, but on a greatly enhanced basis, the proper disposition of radioactive waste presents a legal as well as an engineering problem.

One way of solving the radioactive waste problem would be to find some means of utilizing these fission fragments. Some proposals have been made, but no really sound approach has developed to date. Since to conserve our uranium resources it is necessary to reprocess the nuclear fuel, and since it is not inconceivable that every large nuclear power plant in the future will have a reprocessing plant as an adjunct, it can easily be seen that the waste problem is not only intriguing but serious. Its solution presents a challenge and a field which is wide open for the application of sound engineering principles.

SUMMARY

This paper has shown that the field of nuclear power engineering is still in its infancy. In fact, America's first power-producing reactor has just been put into operation. The field is still wide open to engineers with an open mind and a flair for the unusual. Privately financed studies of reactor technology by four industrial groups associated with the public utilities industry have been working in this field for about a year and two of these groups have already made reports to the U. S. Atomic Energy Commission on the engineering problems and industry's role in the design, building and operating of power reactors.

With the increasing interest in higher temperatures in our power-producing units, a new field of high-temperature materials will have to be developed for nuclear reactors, as present-day superalloys are not compatible with the nuclear requirements of materials of construction for power reactors.

From a metallurgical viewpoint, nuclear engineering will change many of our present-day concepts of specifications of materials. Residual elements, which are of very little concern today, will be watched very closely in order to minimize the effects on the critical mass for a given reactor. This means a refinement of the metallurgical and chemical processes for the future.

The benefits to mankind from this new engineering field will be many. Areas of limited water supply will be able to produce their own power. This should help to put new industries in locations where they never may have existed if nuclear power were not available.

If nuclear power engineering is to take its rightful place in the field of power production, it will do so rapidly only with the help of the engineer. This will occur when the engineer himself becomes interested in its potentialities and is conversant with the basic scientific principles of the field.

Advertisement

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

How VANADIUM improves engineering steels and helps conserve critical alloys

In these critical times when many alloying materials are scarce, you may be able to use vanadium to good advantage. Steels alloyed with vanadium meet most of the mechanical specifications for low-alloy engineering and structural steels. In fact, vanadium can often be used in engineering steels to replace at least part, if not all, of certain alloys now in critical supply.

The metallurgy of vanadium is well known. Small additions of vanadium—0.10 to 0.30 per cent—can be used effectively to give steel extra strength, toughness, and resistance to fatigue and wear. It improves engineering steels by increasing their yield strength without sacrificing ductility. The uniformly fine grain size of vanadium-bearing steels makes them tough and resistant to abrasion, fatigue, and impact.

Better Mechanical Properties

In the following table are typical analyses for carbon-vanadium and chromium-vanadium steels that are suitable for most applications where low-alloy, high-strength steels are required. The carbon-vanadium steel is compared with plain-carbon steel; and the chromium-vanadium steel, with chromium-molybdenum steel. Note the excellent properties of the vanadium-bearing steels.

Fig. 1 — Vanadium increases the strength, toughness, and wear resistance of engineering steels for many machine parts, such as this large crankshaft.

Improves Cast Iron

A small addition of vanadium, usually from 0.10 to 0.25 per cent, refines the grain of cast iron, and materially increases its strength and hardness. Moreover, vanadium may be used in cast iron to replace at least part, if not all, of certain alloys that are now in short supply.

Vanadium in Rimmed Steel

An addition of approximately 1 lb. of vanadium per ton of steel produces non-aging characteristics in a rimmed steel. These non-aging properties, together with improved deep-drawing characteristics and the good surface inherent in rimmed steels, make these steels of particular interest at the present time.

Grades of Ferrovanadium

ELECTROMET produces ferrovanadium containing 50 to 55 per cent vanadium for the production of vanadium-bearing steels and irons. The alloy is produced in three grades with maximum 0.20, 0.50, or 3.00 per cent carbon and maximum 1.50, 2.00, and 8.00 per cent silicon, respectively. Each grade is specially adapted to fill the different requirements of iron- and steel-making.

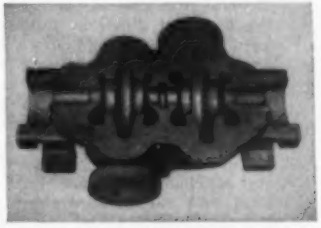


Fig. 2—Steel and iron castings treated with small additions of vanadium have high ductility and greater toughness and impact resistance.

Write for a copy of the booklet, "ELECTROMET Products and Service," which gives helpful information about the use of ferrovanadium and other alloying metals that ELECTROMET supplies. The booklet may be obtained from any ELECTROMET office: in Birmingham, Chicago, Cleveland, Detroit, Los Angeles, New York, Pittsburgh, or San Francisco. In Canada: Welland, Ontario.

Properties of Vanadium Steels Compared With Other Engineering Steels

Typical Analysis, %	Carbon Steel	Carbon-Vanadium Steel	Chromium-Molybdenum Steel	Chromium-Vanadium Steel
Vanadium	—	0.16	—	0.16
Carbon	0.50	0.49	0.50	0.50
Manganese	0.71	0.77	0.80	0.79
Silicon	0.19	0.15	0.30	0.31
Chromium	—	—	0.95	0.98
Molybdenum	—	—	0.20	—
Annealed and Furnace-Cooled				
Tensile Strength, psi	90,600	100,000	100,000	99,500
Yield Point, psi	48,900	66,000	50,000	64,100
Elongation in 2 in., %	23.3	25.0	23.0	28.4
Reduction of Area, %	37.8	49.1	45.0	59.0
Izod Impact, ft.-lb.	13.5	26.0	17.0	44.0
Quenched and Tempered				
Tensile Strength, psi	134,900	134,500	232,000	232,800
Yield Point, psi	110,800	128,000	214,500	224,200
Elongation in 2 in., %	18.3	18.3	10.0	10.4
Reduction of Area, %	54.1	56.6	39.0	43.1
Izod Impact, ft.-lb.	54.0	65.0	12.0	12.0

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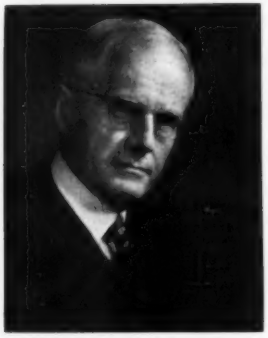
Personal Mention



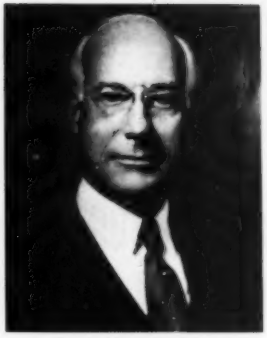
Paul D. Merica

PAUL D. MERICA ⊜, executive vice-president and a director, was elected president both of the International Nickel Co. of Canada, Ltd., and its U. S. subsidiary, International Nickel Co., Inc., May 5. He succeeds in both positions Dr. John F. Thompson ⊜, who continues as chairman of the board of directors and chief officer of both companies. Dr. Merica first became associated with the Company in 1919 as a physical metallurgist at its works in Bayonne, N. J., and he has been successively superintendent of research, director of research and assistant manager of development and research. Becoming technical assistant to the president in 1931 and assistant to the president in 1932, he was elected to the board of directors in 1934 and was made a vice-president in 1936, remaining in general charge of the Company's research activities. He was elected executive vice-president in 1949 and is a member of the executive and advisory committee. He is also a director of the following companies: The American Metal Co., Ltd., The Babcock & Wilcox Co. and Whitehead Metal Products Co., Inc. Dr. Merica is a director and former vice-president of the American Institute of Mining and Metallurgical Engineers, a member of the National Academy of Sciences, a fellow of the American Association for the Advancement of Science, and a member of the American Iron and Steel Institute, American Society for Testing Materials, American Physical Society, Institute of Metals and the Iron and Steel Institute (both of Great Britain), and Canadian Institute of Mining and Metallurgy. Originator of the "precipitation theory" of hardening of alloys, developed in connection with research on aluminum alloys, Dr. Merica has evolved numerous iron-nickel and copper-nickel alloys, including K-Monel (by Merica and Mudge), and is the author of many technical papers and articles. For his contributions in the field of metallurgy and outstanding leadership in physical metallurgy, he was awarded the James Douglas Medal, in 1929; the John Fritz Medal, in 1938; the Institute of Metals Medal, in 1941; the Franklin Institute Medal, in 1942; and the ⊜ Gold Medal, in 1951.

Fred Beitner ⊜ has been appointed midwestern district sales manager by the Trent Tube Co., subsidiary of the Crucible Steel Co. of America. Mr. Beitner has been associated with Trent Tube for six years and will make his headquarters in Pittsburgh.

Harry C. Brainard ⊜ has been appointed chief metallurgist for The Cleveland Chain & Mfg. Co., Cleveland. He has assumed direction of the company's entire metal development program and also will supervise quality control. Prior to joining Cleveland Chain, Mr. Brainard was connected with Lyon, Inc., Detroit, and the Cyclops Steel Co., Titusville, Pa. At Cleveland Chain he has been largely responsible for developing a superior alloy steel chain and for new techniques in welding alloy steel.

Harry E. Orr ⊜ has been appointed assistant vice-president and manager of engineering sales of the Vanadium Corporation of America, with headquarters in Chicago. **John B. Girdler** ⊜, formerly regional manager in the Pittsburgh office of Vanadium, has been appointed sales manager of the Corporation.



Bradley Stoughton

BRADLEY STOUGHTON ⊜, director and consulting metallurgist of the Lukens Steel Co., has received a Department of the Army award for his contribution to World War II effort in industrial intelligence. A certificate of appreciation, signed by Secretary of the Army Frank Pace, Jr., was presented to him in a ceremony held at Lehigh University. Dr. Stoughton was London representative of the Technical Industrial Intelligence Committee, which worked closely with the Joint Chiefs of Staff. He was awarded his doctorate in engineering at Lehigh University in 1896. Dr. Stoughton has served on the faculty of Massachusetts Institute of Technology, Columbia University, and more recently at Lehigh University, where he served as professor of metallurgy. From 1923 until 1939 he was also dean of the College of Engineering. In 1941 Dr. Stoughton became chief, heat treating equipment, tool section, War Production Board, and later he served as acting head of foundry equipment section of WPB. In 1929 he was awarded the Grasselli Medal by the Society of Chemical Industry. In 1939 the Lehigh Valley Chapter ⊜ established an Annual Stoughton Night and in 1943 the Bradley Stoughton Award for outstanding contribution to metallurgy by a member of the Lehigh Chapter. Dr. Stoughton was a tour escort last fall at the World Metallurgical Congress for the group of foreign conferees visiting steel refining and steelmaking plants in this country. He is the author of "The Metallurgy of Iron and Steel" (1908), and "Engineering Metallurgy", with Allison Butts (1926).

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Personals

Walter E. Remmers was recently elected vice-president of the Alloys Division, Union Carbide and Carbon Corp. He has been president of Electro Metallurgical Co. since 1948 and president of United States Vanadium Co. since 1950. Both companies are divisions of Union Carbide and Carbon Corp.

Jerome J. J. Schlass is now vice-president and sales manager of Weldwire Co., Inc., Philadelphia.

Dave Heckinger has rejoined the sales engineering staff of Fansteel Metallurgical Corp. at the main office in North Chicago. Prior to 1948, Mr. Heckinger was a Fansteel sales representative in branch offices at Chicago, St. Louis and Philadelphia.

Otis R. Carpenter has been appointed an executive assistant of the Barberton, Ohio, works of The Babcock & Wilcox Co. His previous position was as director of the Works Control Laboratory at the Barberton works.

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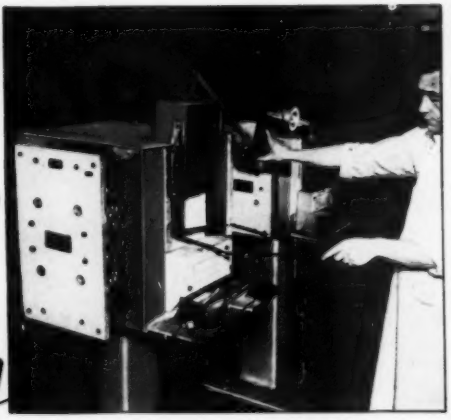

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James M. Robertson, who has been associated with the Wellman Bronze & Aluminum Co., Cleveland, for the past ten years, for the last year as head of the laboratory, has been appointed chief chemist in charge of quality control at all plants. **Robert C. Boehm** is the company's new chief metallurgist. For the last six years he was engaged in research on castings for the Aluminum Co. of America and for three years before that he was a metallurgist for the Ohio Crankshaft Co., Cleveland.

Ernest H. Klein, manager of the metal division, New Jersey Zinc Sales Company, New York, was elected president of the Metal Powder Association at the eighth annual meeting of the Association held in Chicago. He succeeded **Thomas L. Robinson**, president of the Wel-Met Co., Kent, Ohio, who was elected chairman of the board. **George Roberts**, of the Vanadium-Alloys Steel Co., Latrobe, Pa., was elected to the board of directors.

E. S. Schwartz has been promoted to vice-president of H. Kramer & Co., Chicago. He is also general works manager of plants in Chicago, Philadelphia (Ajax Metal Division) and Los Angeles.

L. B. Stark has left the U. S. Navy Electronics Laboratory, San Diego, Calif., where he was in charge of the metallurgy section, to accept the position of project coordinator of the manufacturing development group, planning and tooling department, Consolidated Vultee Aircraft Corp., San Diego.

Walter W. Edens has been appointed to the sales engineering staff of the Federated Metals Division, American Smelting and Refining Co. He will be concerned primarily with the foundry trade. Before joining Federated, Mr. Edens worked in an executive capacity with the Heil Co. and with Ampco Metal, Inc., as chief metallurgist and foundry superintendent. He has been vice-president of the Badger Brass & Aluminum Foundry Co. in Milwaukee and defense projects executive administering Navy and Air Force casting development contracts for the Alloy Engineering & Casting Co., Champaign, Ill. He also served recently as a member of the technical advisory committee to the foundry industry committee of the Munitions Board.

Machine tool idea pool

In designing machine tools, as in planning countless other products, OSTUCO Steel Tubing provides an endless pool of practical ideas because of its *unlimited adaptability*. Collets, chucks, spacers, spindles, bearings, shafts, ferrules, and handles are but a few of the applications.

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Personals

Robert H. Farley has been recalled to service with the U. S. Air Force as a captain and is now stationed at Keesler Air Force Base, Miss.

Donald P. Kedzie, who graduated from the University of Houston last February, has taken a position in the metallurgical research department of A. O. Smith Corp., Milwaukee, Wis.

Robert H. Caughey, assistant chief metallurgist at M. W. Kellogg Co., Jersey City, N. J., has been appointed to membership on the interim advisory committee on alloy steels, refining section, American Petroleum Institute.

George H. Eichelman, Jr., formerly with the research laboratories of Westinghouse Electric Corp., East Pittsburgh, Pa., is now employed by The American Brass Co. at the metallurgical research laboratory in Waterbury, Conn.

Arthur R. Lytle has been appointed director of research at Union Carbide and Carbon Research Labs., Inc., Niagara Falls, N. Y. **Walter Crafts** has been appointed associate director of research, and **David Swan**, assistant director of research. These laboratories are the primary metallurgical laboratories for Union Carbide and Carbon Corp. and carry on metallurgical research for Electro Metallurgical Co., Haynes Stellite Co., Linde Air Products Co., and other divisions of the Corporation.

Mr. Lytle, who will move from Niagara Falls to New York, has been associated with the Union Carbide laboratories for 29 years. For the past two years, he has been responsible for all the metallurgical research activities there. Before then, he carried out and directed extensive research on the welding of metals. He developed many new welding rod compositions, including the first nonfuming bronze. Mr. Lytle also pioneered in the field of automatic welding machines, and was responsible for many advances in the use of the oxy-acetylene flame for hardening, powder-cutting, and pressure-welding processes.

Mr. Crafts has been chief metallurgist at the Niagara laboratories since 1946. Among the projects that he has handled has been the development of various alloy addition agents used in making steel and cast iron. His work on steelmaking and deoxidation, as well as on the hardenability and properties of alloy steels, has been described in many papers presented before the American Institute of Mining and Metallurgical Engineers and . Mr. Crafts is co-author of two books, one on "Hardenability and Steel Selection", and the other on "Alloys of Iron and Chromium".

Mr. Swan joined the Niagara laboratories in 1946. Recently, he has been in the New York offices as research engineer, but he will move back to Niagara Falls when he assumes his new responsibilities. His work has been concerned principally with special studies of the use of various alloys and metals used in making steel and cast iron.

J. B. R. Anderson, resident service metallurgist for the New York district of U. S. Steel, is temporarily on loan to the metallurgical and conservation branch of the iron and steel division, National Production Authority, Washington, D. C.

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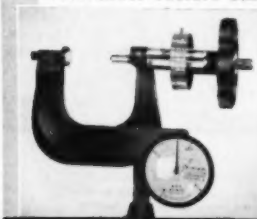

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Personals

Albert G. Guy ⊖ will join the staff of Purdue University's school of chemical and metallurgical engineering effective in September. He received the degree of D.Sc. from Carnegie Institute of Technology in 1944 and has since worked for the General Electric Co., the Office of Ordnance Research, and was associate professor of metallurgy at North Carolina State College. He has been appointed an assistant professor at Purdue.

H. George De Young, works manager of Atlas Steels Ltd., Welland, Ont., has been appointed vice-president of operations. Mr. De Young came to Atlas from Treadwell Engineering Co., Easton, Pa., where he was assistant to the president. After graduating from the U. S. Naval Academy at Annapolis, Md., he had served the Midvale Co., Philadelphia, for 18 years in their manufacturing operations. During the war he received an award from the U. S. Government for his work in connection with the development of armor piercing projectiles.

James D. Glenn ⊖, general manager of stainless steel sales at Crucible Steel Co. of America, has accepted appointment as chief of the stainless steel section, iron and steel division, National Production Authority, with headquarters in Washington. Mr. Glenn will be on leave from Crucible. Since entering the steel industry in 1927, Mr. Glenn has specialized in stainless and alloy steel sales activities. He first was associated with the Central Alloy Steel Corp. in Massillon, Ohio. In 1930, he joined the Associated Alloy Steel Corp. in Cleveland, Ohio, a sales organization for the stainless and alloy steel products of three companies, including Sharon Steel Corp. In 1933, after the Associated Alloy Steel firm was dissolved, Mr. Glenn joined Sharon Steel as assistant manager of the stainless steel division. He became manager of stainless and alloy steel sales in 1937, and in 1944 was made assistant general manager of sales of the entire company. In February 1945 Mr. Glenn became associated with Eastern Stainless Steel Corp., Baltimore, Md., as vice-president in charge of sales. He came to Crucible Steel Co. in 1948.

T. G. McNamara ⊖, formerly associate project director, casting potentials project, Alloy Engineering & Casting Co., Champaign, Ill., is now chief metallurgist at the Bridgeport-Lycoming Division, Avco Mfg. Co., Stratford, Conn.

Martin L. Killgallon ⊖, formerly plant manager, Berry Division, Oliver Iron & Steel Corp., Corinth, Miss., is now technical assistant works manager of the Mueller Brass Co., Port Huron, Mich.

F. R. H. Allon ⊖, after completing a one-year tour of Canadian and American steel foundries, sponsored by the Mond Nickel Co., has taken a position as chief metallurgist with Catton & Co., Ltd., Leeds, England.

Arnold A. Ulmer ⊖, who graduated from the South Dakota School of Mines and Technology last June, has taken a position in the manufacturing engineering department of Westinghouse Electric Corp., Sharon, Pa.

Hamilton Migel ⊖ has been appointed to the newly created position of second vice-president in charge of engineering at the Magnaflux Corp., Chicago. He will have over-all direction of both research and design engineering.

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Corrosion Studies

(Continued from p. 89)

able rust, although the steels with chromium contents of 3% or more showed comparatively better resistance to corrosion. A low-carbon steel with very low copper (0.01%) corrodes 11 times faster at this location than at the atmospheric test lot 800 ft. away where spray seldom reaches. At the latter, a paint composed of sodium silicate and zinc dust has given good protection to steel in a test that is now past the fifth year. Cadmium plating has been found superior to that of zinc, which contradicts results obtained by some test stations under supposedly similar atmospheric conditions. Titanium metal is being tested also, and to date (the test is now in its fourth year) it has developed only a slight film or discoloration and this is easily removed with a light rubbing of a pencil eraser.

In addition to the outdoor tests, a large amount of work is done in the laboratory building at Harbor Island to determine the ability of alloys to withstand erosion when used in condenser tubes, piping, propellers and underwater parts of ships. Equipment used for these studies includes the EES Erosion Testing Apparatus (developed by the U. S. Naval Engineering Experiment Station at Annapolis) that whirls bars or tubes at velocities up to 30 ft. per sec. in violently agitated sea water, rotating spindles and impingement test apparatus. The latter equipment is of two kinds: the aspirator type invented at Kure Beach which mixes air bubbles with sea water, and the impingement test apparatus designed and built by the British Nonferrous Metals Research Laboratory with whom cooperative studies are being made.

J. P.

Testing Cemented Carbides*

TO PROMOTE a better understanding of carbide materials, to encourage a more intelligent application of carbide tools, as well as to further the standardization of test-

(Continued on p. 126)

*Abstract of "Methods of Testing Cemented Carbide Compositions", by A. D. Stevens and J. C. Redmond, a paper presented before the American Society for Testing Materials at Cleveland, March 1952, as part of the Symposium on Testing Metal Powders and Metal Powder Products.

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Testing Cemented Carbides

(Continued from p. 124)

ing methods, Stevens and Redmond of Kennametal have investigated tests now prevalently used. Four groups of tests are discussed.

The authors propose a more accurate description for the hard carbide tool materials than the words "cemented" and "sintered" now used. In the metallurgical reaction which forms commercial carbide materials, the auxiliary metal (usually cobalt) partially dissolves the tungsten carbide particles at elevated temperatures. Subsequent cooling precipitates the dissolved tungsten carbide on the residual carbide particles, resulting in a continuous carbide skeleton or network containing the nearly pure cobalt in the interstices. The cobalt acts not as a cement, but as a vehicle for producing a carbide-to-carbide union at a temperature far below the melting point of the carbides. The word "pyromerge" is proposed to distinguish this reaction from true cementing or true sintering.

Carbide cutting tools are classified into four groups, according to the application. The groups are:

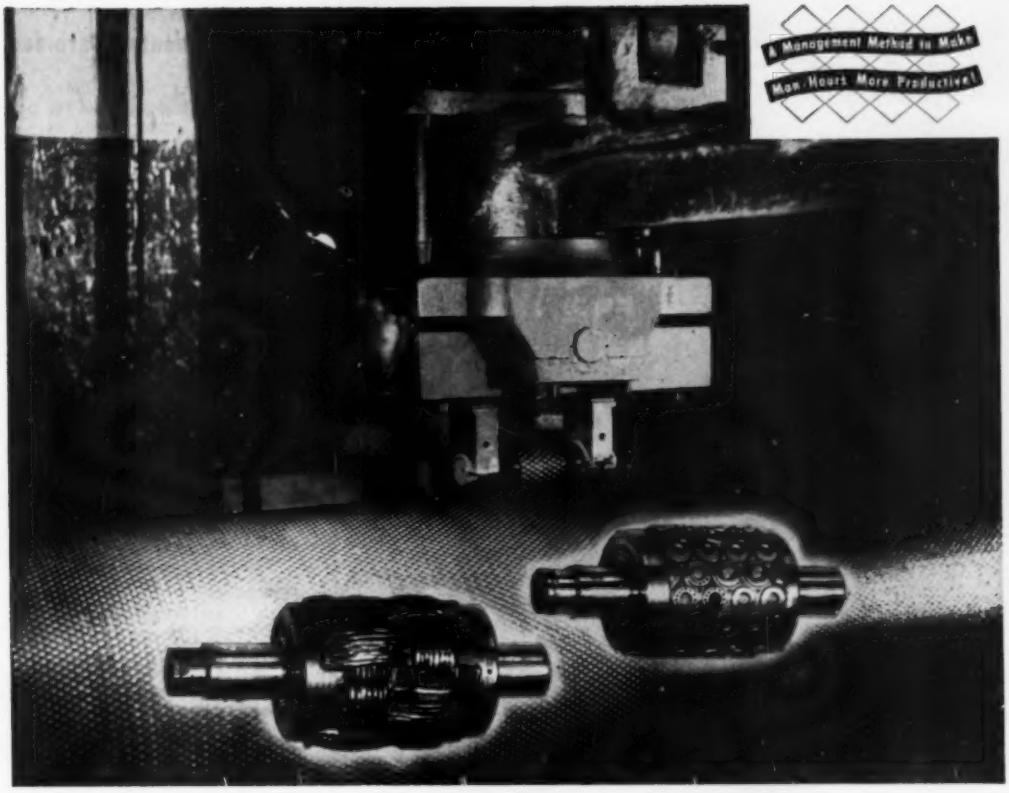
1. Cast iron and nonferrous metal cutting.
2. Steel cutting.
3. Wear or abrasion resistant.
4. Shock resistant.

With the exception of the steel cutting group, they are essentially tungsten carbide and cobalt compositions.

When the WC-Co compositions are used for steel cutting, tool failure occurs not in edge wear, but as "cratering". Cratering results from the continuous steel chip welding intermittently to the tool surface behind the cutting edge. The driving force of the chip, combined with this localized welding, causes removal of the tool material, forming a depression immediately behind the cutting edge. The cutting edge then crumbles due to lack of support. Certain so-called "alloy" carbides, TiC, TaC, or CbC, when added to the WC-Co material, retard the cratering. Because these alloy carbides are higher melting than WC and have a lower thermal conductivity, the tendency of the hot steel chip to weld to the tool is reduced. More rapid wear of the tool edge occurs because these alloy carbides lower the strength of the resultant tool material.

Tests can be applied either for quality control of the raw materi-

(Continued on p. 128)



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Testing Cemented Carbides

(Continued from p. 126)

als, or for the inspection of the finished product. The usefulness of any test or inspection method must recognize the physical (pyromerged) character of the material.

The four types of tests considered were chemical, physical, metallographic, and X-ray.

The chemical tests have the drawback of being destructive. Either the spectrograph is used with reference to standard plates, or a wet analysis which requires both time and technique beyond the disposal of the routine chemical laboratory.

Three useful physical tests were discussed: *(a)* Specific gravity, *(b)* transverse rupture, and *(c)* hardness.

The specific gravity measurement is useful only if the approximate analysis is known.

Component	Specific Gravity
Cobalt	8.9
Tungsten carbide	15.5
Titanium carbide	4.9
Tantalum carbide	14.5
Columbium carbide	7.8
Steel cutting grades	above 9
Nonsteel cutting grades	above 14
Shock and wear resistant	above 13

The transverse rupture test, which is a destructive test, has not been standardized for carbide cutting tools, although it is an integral part of manufacturing quality control. A minimum specimen dimensional ratio must exist for proper interpretation, and at present such a ratio is seldom attained.

The hardness test (Rockwell A) is most useful when correlated with other tests. Inconsistencies have been found because of poor machine calibration, and porosity, which leads to reading variations. The Rockwell C (150-kg. load) test cannot be used because it causes considerable diamond brale breakage. To secure consistent and reproducible hardness indications, the specimen surface must be prepared by wet diamond grinding (200 or finer grit, 0.001-in. maximum cut). The Rockwell machine must be calibrated before each series of readings, and the carbide must also be given good parallel support when loaded.

Metallographic examination for amount of porosity is made at 200×, and in the etched condition at 1500× for the continuity of particle-to-particle bonding. Porosity above approximately 1% will give incor-

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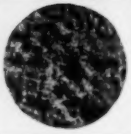	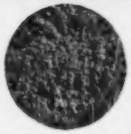

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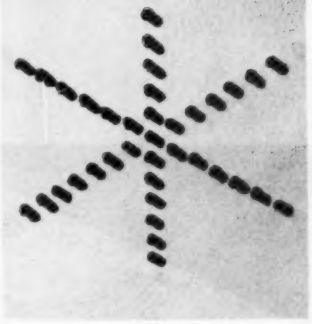

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DESIGNERS & BUILDERS OF SPECIALIZED METAL CLEANING EQUIPMENT

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ABBOTT
ABBOTT
BURNISHING
MATERIALS
& BARRELS
for SUPERIOR RESULTS
Manufacturers of Deep Hardened and
Tempered Carbon Steel Bearing Balls
THE ABBOTT BALL CO.
1049 New Britain Ave., Hartford, Conn.

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RHODIUM Plating

In these days of restrictions on the use of the usual plating metals, the precious metal, rhodium, becomes important as a replacement for them, especially for small articles and parts.

Rhodium is hard and brilliantly white and it cannot tarnish. No acid nor mixture of acids attack it. Our solution has excellent throwing power.

Suggested objects for plating with rhodium are optical mounts, contacts for communication equipment, radar components, surgical instruments and pen and pencil sets. The practical plater's own experience will suggest many others to him.

Commercial rhodium plating was developed in our laboratories. Baker Rhodium Plating Solution is the original and is made under the direction of the men who developed the process.

● Let us send you *Directions for Rhodium Plating.*

Baker & Co., Inc.

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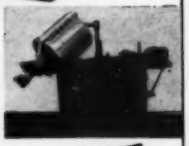
For economical bulk plating with fast loading and unloading features investigate the Daniels DLS Plating Barrels. Write for illustrated catalog today.



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Use . . .
Hangsterfer's
LUBRICANTS
for . . . Increased Production
Less Scrap
Longer Die Life

Doing the most difficult jobs for the major metalworking plants throughout the United States and Europe.

HANGSTERFER'S LABORATORIES, INC.
21 Cooper Street • Woodbury, N. J.

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Sure-Wear
Heat Treating

"Sure-Wear"—to ensure longer life in all types of high speed cutting tools!

L-R Heat Treating Co. research has developed a new process for heat treating of all types of high speed cutting tools to ensure longer tool life than ever before.

Specify "Sure-Wear" to be sure.

"Mirror-Finish" is another L-R exclusive process. Ask for details.

L-R is equipped for quantity production work. Metallurgical and laboratory service available.

Tool and Die Hardening . . .
Precision Heat Treating . . .
Salt high speed steel martempering . . .
Cyaniding . . . Pack Hardening
Annealing . . . Normalizing
Brazing . . . Nitriding
Also all non-ferrous Heat Treating
Pick-up and delivery (5 Trucks)

LR HEAT TREATING CO.
QUALITY STEEL TREATING
107-11 VESEY ST. NEWARK 5, N. J.
Equipped for Large Quantity Production Work

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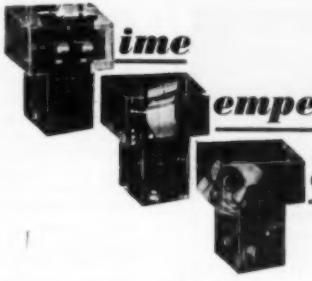
first in the Three T's of Scientific Steel Treating...

WHETHER it's the treating of your rough forgings, castings and bar stock, or your finish-machined parts—the 3 T's of Scientific Steel Treating are at work for you. From the unbiased, scientific recommendations of your Lakeside metallurgists, through the perfected, fully mechanized, electronically-controlled processes, to instrumented, precision testing—Science directs every step. No chance for guesswork, or human error. Only with the finest, modern facilities can you be assured of *highest steel treating quality.*



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Our Services— Electronic Induction Hardening, Carbo-nitriding, Flame Hardening, Heat Treating, Bar Stock Treating and Straightening (mill lengths and sizes), Annealing, Stress Relieving, Normalising, Pack, Gas or Liquid Carburizing, Nitriding, Speed Nitriding, Aerocasing, Chapmanizing, Cyaniding, Sand Blasting, Laboratory Research, Tensile and Bend Tests.

THE *Lakeside Steel Improvement Co.*

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Large Car Bottom Furnaces
Pit Type Convection Furnaces
Production Batch Furnaces

Carbonitriding
Controlled Atmosphere
Cyanide and Neutral Baths
Carburizing
Induction Heating
Normalizing
Annealing
Grit Blasting
Shot Blasting

Complete Heat Treating Facilities...

FORGINGS, CASTINGS, TOOLS, PARTS

Special Jobs or Production Runs
Complete Heat Treating
Counsel Without Obligation

Send for Free Booklet of Complete Facilities

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Spotlighting
DETROIT'S BETTER
HEAT TREATER

OFFERING FACILITIES FOR:
1. ALUMINUM-CAP. 500,000# PER MO.
2. MINUTE PARTS TO 2-TON OVER
3. BRIGHT HARDENING OF STAINLESS STEEL

ALL TYPES OF HEAT TREATING CAN BE DONE BETTER BY
STANDARD STEEL TREATING CO.
3467 LOVETT AVE. DETROIT 10, MICH.
Phone TAshmoo 5-0600

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Heat Treating
OF METALS

Flame Hardening	Stress Relieving
Induction Hardening ★	Normalizing
Chapmanizing	Gas, Pack or Liquid Carburizing
Nitriding	Annealing
Cyaniding ★	Silver-Finish Hardening of Dies or Tools
Cadmium, Tin or Copper Plating ★	Roto-Blasting
Anodizing or Alrocking of Aluminum	Silver or Copper Brazing

PITTSBURGH COMMERCIAL HEAT TREATING CO
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HAYS DIAFLOW METER

New low differential flow meter measures:

1. air flow
2. gas flow
3. or air flow–gas flow ratio

Diaflow measurement in open hearth, soaking pit, billet, slab heating and annealing furnace indicates excessive amounts of air and/or gas... helps to prevent fuel and gas waste... serves as a guide in maintaining product quality.

Write for bulletin 52-1017-37

BULLETIN ON HEAT TREATING FURNACES

A complete summary of Hays products applicable to processes such as annealing, brazing and calorizing. Scope includes various methods of firing (underfired, overfired, sidefired), fuel burned (gas, coal, oil), and type of furnace (continuous, rotary hearth, slab heating, etc.).

Hays complete line of draft gages, flow gages and meters (for high and low pressure gases and liquids), portable gas analyzers and automatic CO_2 recorders are covered.

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43rd YEAR
A VINCENT PROCESS
For
EVERY HEAT TREATING NEED
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300-TON DAILY CAPACITY
•
MODERN FACILITIES
VINCENT
STEEL PROCESS CO.
2424 Bellevue Ave. • Detroit 7, Mich.

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HEAT TREAT at it's *Best!*

COMPLETE SERVICE including —
BRIGHT HARDENING OF STAINLESS STEELS...STEAM TREATING HIGH-SPEED CUTTING TOOLS ... HARDENING ... TEMPERING ... CLEANING.
Our Metallurgical Engineers can help with your metal treating problems.

COMMERCIAL STEEL TREATING CORP.
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TYler 6-6086

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Serving the
HEAT TREATING INDUSTRY
Since 1930

- Complete Service on Control Equipment
- Thermocouples
- Protection Tubes
- Charts and Lead Wire

THE CLEVELAND ELECTRIC LABORATORIES COMPANY

1988 E. 66 St. Cleveland 3, Ohio

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Control Temperatures More Closely
REDUCE COST • SAVE TIME

This Catalog of Improved Pyrometer Supplies shows you how!

Get your FREE Copy Today!

★ Thermocouples ★ Protection Tubes
★ Thermocouple Wire ★ Lead Wire
★ Insulators ★ Terminal Heads

ARKLAY S. RICHARDS CO., Inc.

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CIRC-AIR
HEAT TREATING FURNACES
for Every Heat Treating Process

★
CONTROLLED ATMOSPHERES
★
DIRECT FIRED
★
CIRC-AIR DRAW FURNACES
★
CIRC-AIR NICARB
(CARBONITRIDING)

Specially Engineered for Your Particular Needs

GAS • OIL • ELECTRIC

INDUSTRIAL HEATING EQUIPMENT

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Park

- PARK-KASE LIQUID CARBURIZERS
- QUENCHING and TEMPERING OILS
- CYANIDE MIXTURES
- NEUTRAL SALT BATHS
- HIGH SPEED STEEL HARDENING SALTS
- TEMPERING and ISO-THERMAL QUENCHING SALTS
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- CARBON PRODUCTS
  Charcoal • Crushed Coke
  Pitch Coke • Lead Pot Carbon
- WOODSIDE RAPID CARBURIZERS
  Non-Burning Type
  Charcoal Coke
  Specifications

PARK CHEMICAL COMPANY
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EXPLOSION COMBINATION GAS and OIL BURNER

Our burners afford low fuel consumption, substantially complete combustion (11½% CO_2 Orsat), instant lighting without preheating. Never need cleaning. Absolute metering of fuel by single control. Rapid recovery of temperature head.

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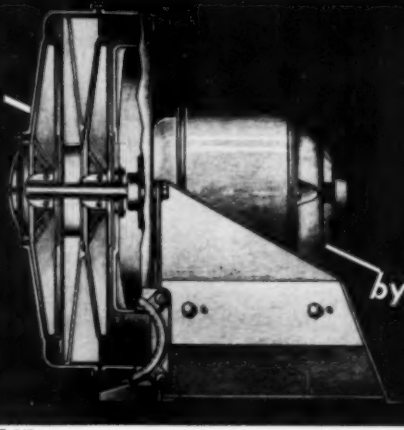

by North American Manufacturing Company
GAS OR OIL COMBUSTION EQUIPMENT
CLEVELAND 5, OHIO

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FREE

the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .

KELCO

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GAS, OIL AND ELECTRIC
BATCH • CONTINUOUS

ATMOSPHERIC - RECIRCULATING - PUSHER — ROTARY HEARTH — CONVEYOR — RADIANT TUBE - POT CAR-BOTTOM - ALUMINUM REVERBS.

"Tailored by Dempsey"

DEMPSEY FURNACES

DEMPSEY INDUSTRIAL FURNACE CORP.
Springfield 1, Mass.

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MERIAM MANOMETERS

U-TYPE • WELL TYPE • DUAL TUBE

FLOW METERS
DRAFT GAUGES

For measuring pressure, vacuum and differential pressure of liquids and gases. Also a complete line of accessories.

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U-TYPE MANOMETER

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Non-Case

Anti-Carburizing Paint

Applied to any part of a steel surface prior to carburizing, Non-Case protects that specific portion from carburization and hardening. Easy to use, Non-Case is available in gallon cans.

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Engineered and Built to Your Specific requirements.

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Special and standard furnaces for annealing, normalizing, hardening, drawing, forging, heat treating.

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Free Descriptive Bulletin on Request.

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Phone: STate 2-4071

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for Fast and Efficient
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Use the BARBER COLMAN *Impressor*

ON ALUMINUM, COPPER, BRASS, BRONZE, PLASTICS

Works on the principle of forcing a hardened, spring-loaded steel point into the surface, the amount of penetration registering instantly on a dial indicator to give a dependable measure of hardness. Can be used in any position. Simple to operate. Ruggedly built. Thousands in use.

Write for Bulletin 1689-1

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CLEVELAND
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HOUSTON
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2221 Telephone Rd.

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Control Engineering Co.
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Atmosphere Annealing
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Heat Treating
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Metallurgical Experiments
Powder Metallurgy
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Salt & Lead Bath Tempering
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Ask for Catalog 5201

You tell Boder what you need.

BODER SCIENTIFIC CO
719-723 Liberty Ave.
PITTSBURGH 22, PA.

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Headquarters for
NON-DESTRUCTIVE TESTING
and
MEASURING INSTRUMENTS
★ ★ ★
ULTRASONIC & MAGNETIC INSPECTION EQUIPMENT
Crack & Defect Locators
Metal Sorters
Ultrasonic Thickness Gages
ELECTRONIC MICROMETERS
For production measurement of precision components to within 0.000020 in.

J. W. DICE CO.
ENGLEWOOD, N. J.
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If you want to perform
Tensile or Brinell testing operations
quickly and simply—*contact*

Detroit Testing Machine Company
9330 Grinnell Ave. • Detroit 13, Mich.

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Solve
INSPECTION DEMAGNETIZING SORTING PROBLEMS *with*
MAGNETIC ANALYSIS EQUIPMENT

Electronic Equipment for non-destructive production inspection of steel bars and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

This Equipment is now employed by more than 40 Steel Mills and many Steel Fabricators.

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Electrical Equipment for efficient production demagnetizing of steel bars and tubing. When used with Magnetic Analysis Equipment inspection and demagnetizing can be done in a single operation.

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Electronic instruments for production sorting of ferrous and non-ferrous materials and parts for variations in composition and physical properties.

ALSO MAGNETISM DETECTORS

Inexpensive pocket meters for indicating magnetism in ferrous materials and parts.

"THE TEST TELLS"

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TESTING-ANALYZING

Small jobs are part of our daily routine. Whether a $5.00 job or one for $50,000.00 the same personnel, experience and laboratory equipment are available. We encourage the small job. It's the best way to introduce our laboratories to you.

ST & CO., INC. SAM TOUR & CO., INC.

AMERICAN STANDARDS TESTING BUREAU, INC.

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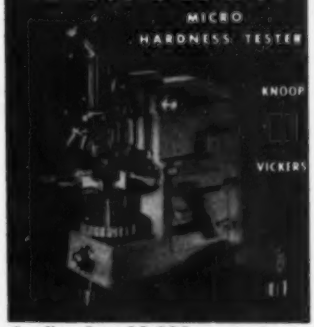
KENTRON
MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads
Write for Bulletin
KENT CLIFF LABORATORIES
PEEKSKILL NEW YORK

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Solve FLAW DETECTION PROBLEMS with

FOERSTER PROBOTESTER

Electronic equipment for non-destructive inspection of *irregularly* shaped iron and steel parts for certain flaws.

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USE OUR
HOEGANAES
SPONGE IRON POWDER
for
Powder Metallurgy
Fabrication
and other
Metallurgical Purposes

EKSTRAND & THOLAND, Inc.
441 Lexington Avenue
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TOOL STEEL
NATIONALLY KNOWN BRANDS

NOW AVAILABLE FROM STOCK

- High Speed: T-1 to T-15, M-1 to M-56
- High Carbon—High Chrome
- Oil Hardening
- Air Hardening
- Water Hardening
- Hot and Cold Work-Die Steel
- Fast Finishing Steels

COMPLETE WAREHOUSE FACILITIES

STOCK LIST MAILED ON REQUEST

RELIABLE STEEL CO.

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"SILVERCOTE"®
BERYLLIUM COPPER

BRONZES • ALUMINUM
COPPERWELD • SILVER PLATED WIRES
OTHER NON-FERROUS

ROUND WIRE FLAT
for
* SPRINGS
* FORMS
* ELECTRONICS
* SPECIAL PURPOSES

LITTLE FALLS ALLOYS
INCORPORATED
189 Caldwell Ave. • Paterson 1, N. J.

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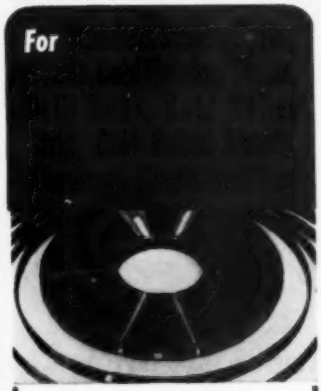
For



Stainless Steel in strip, sheet, bars, tubing and accessories.

Cold Finished Steels in all standard shapes and carbon analyses.

Spring Steels in Blue Tempered and Polished Coils, Cold Rolled Annealed Coils and Straight Lengths in 1070 and 1095 Carbon grades and Hot Rolled SAE 1095 and 9255 Bars. Wires include Polished Music Spring Wire, Black Oil Tempered Spring Wire.

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Planet Drill Rods Rounds sizes from .013 to 2 in. – flats and squares.

Aluminum Sheets in coils and straight lengths in all alloys. – **Aluminum Bars and Rods.**

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ULTRASONICS

for rapid, accurate, non-destructive
THICKNESS MEASUREMENTS
and **FLAW DETECTION** from one side

AUDIGAGE® Thickness Testers
Ranges 0.020" to 4"
and 0.020" to 12"

AUDIGAGE® Ultrasonic Micrometer
Direct-Reading
Special Ranges as required
Accuracy as high as ±0.25%

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electronics development production
439 FAIRFIELD AVE · STAMFORD · CONN.

Literature on Request

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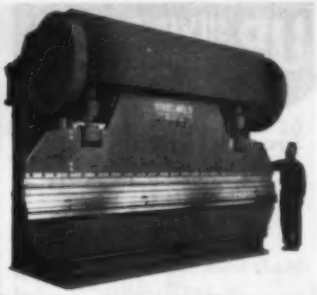
Corrugating and any straight-line production bending can be done to hairline accuracy.

STEELWELD BENDING PRESSES

Large holes can be punched singly. Smaller holes can be punched 25 to 150 at a time.

Conical sections are quickly formed with standard bending dies by use of the ram-tapering mechanism.

Steelweld Presses for bending, forming, blanking, drawing and multiple-punching operations. Complete line for all size metal to 1¼" x 20'-0". Write for free copy of catalog No. 2010.



Steelwelds have heavy duty one-piece welded frames that stay rigid for life. Machinery is top quality throughout and easy to maintain.

THE CLEVELAND CRANE & ENGINEERING CO.

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MAGNESIUM

your comprehensive independent source of magnesium alloy

Tubes • Rods • Shapes • Bars
Hollow Extrusions • Plate • Strip
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WHITELIGHT MAGNESIUM

WHITE METAL ROLLING & STAMPING CORP.

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Sales Office
376 Lafayette St., New York 3, N. Y.

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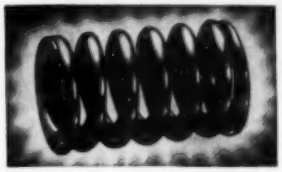

COMPRESSION • TORSION • FLAT • EXTENSION • AND SPECIAL TYPE SPRINGS

METAL STAMPINGS AND WIRE FORMS

JOHN EVANS' SONS, Inc.

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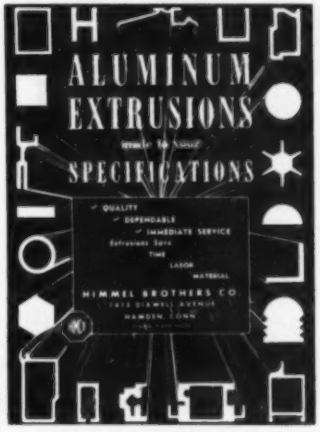

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to the Industrial

Stamping

Fabricating

C. A. DAHLIN meets every Engineering Problem

IF it's intricate or simple...large or small production... ..any metal you name - *Investigate the C. A Dahlin facilities for dependable service and quality workmanship.*

Write today for the C. A. Dahlin Special Bulletin.

C. A. DAHLIN COMPANY

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Phone LAkeview 5-9116

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UP SILVER BRAZING PRODUCTION

with

Stress-Relieved
"No-Tangle" Notch-Coil
Silver Brazing Rings
and Coined Washers

Made from *Silfos* and *Easy-Flo*
in *any* diameter.

Write NOW for samples

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Suburb of Milwaukee

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Use Atlantic Fluxes

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ALUCO...
For degasifying and purifying aluminum alloys. Assures uniformly sound, dense grained castings. Used in reverberatory and crucible type furnaces.

ALUCO 'S'...
Specially compounded for die casting aluminum-base metal and permanent mold castings.

MAGNESAL...
Used for removing magnesium from aluminum alloys

ALUCO 'GR' & 'DG'...
For grain refining and degasifying aluminum and its alloys.

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Atlantic Chemicals & Metals Co.
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CHICAGO 14, ILLINOIS, U.S.A.

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USE HANGSTERFER'S
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for
Broaching
Milling
Tapping
STAINLESS STEELS
and
TITANIUM
Smoother finish
Greater tool life
Increased production

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PROTECT METALS AGAINST

RUST
CORROSION
SCRATCHES
ABRASION

Extensive laboratory facilities are at your service for any rust, waterproofing, or corrosion-resistant problem.

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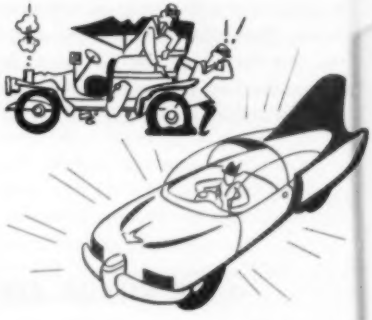
METAL SHOW NEWSletter

METAL KEEPS THE PEACE

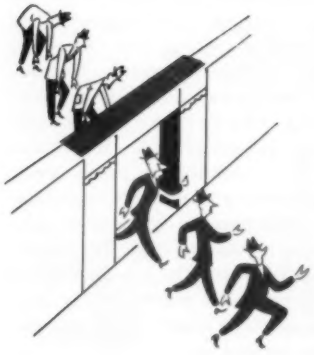
NATIONAL METAL EXPOSITION & CONGRESS · Philadelphia · Oct. 20-24

THE METAL SHOW IS THE PROPER PLACE TO "TRADE IN" OUTWORN IDEAS, CAN'T-BE-DONE ATTITUDES

The Metal Show is distinctly different from any other major industrial show. It's different because it is NOT concerned with one single phase of the vast metals industry—but with all phases, from prime producers to finishers. In this broad, ore-to-finished-product coverage lies the mighty and magnetic force of the Metal Show. No metals industries man can spend a single hour among the exhibits without seeing something that sparks an idea in his mind, without bumping squarely into the newest, the most advanced, the most ingenious use of all the techniques of producing, designing, fabricating, finishing, etc. That's why more and more metals industries men are planning to see the Big Metal Show at Philadelphia—it's the *proving and parade ground of America's finest industrial talents.*



THE GREATEST STIMULANT UNDER THE SUN FOR OVER-WORKED STAFF MEN . . . *Philadelphia in October, '52*



Engineers, metallurgists, designers, production men and their bosses come away from a Big Metal Show with a lighter step, a chin-up, brisk eagerness to get back to their specific jobs and put to work some of the ideas they've picked up! It's a fine and bracing refresher, a visit to the Big Metal Show. Bracing because *it stimulates, enthuses, exhilarates.* It takes something pretty big to do that—and the bigness, the power and the scope of the Metal Show lie not in its physical size but in its deep and enduring impact on the minds and creative spirits of metals men who bring to it tired, jaded minds and bodies—and who leave with renewed energy and a hatful of ideas on how to get things done better, faster, cheaper. That's what makes the time and money required to get staff men to Philadelphia this Fall the *best investment American industry can make today!*

EXECUTIVES ARE LEARNING . . . . . SEE NEXT PAGE

Plan NOW to attend the most important Nationa

ACTION . . . . COLOR-AND-MOTION DISPLAYS WILL ENLIVEN THE BIGGEST METAL SHOW

Exhibitors seasoned in the art of putting their best foot forward long ago saw the wisdom of color and motion in good display—of letting the thousands upon thousands of willing-and-able-to-buy visitors see products in action . . . or that action translated forcefully in displays that catch and hold attention. All this lends a buoyant, colorful atmosphere to the Big Metal Show . . . makes it a place and a time of great achievement and high hopes for the future. And when the men who stop and study your display are the very same men you sell to—or hope to sell to—you've got the moment in your hands every manufacturer dreams about—*the right prospect in the right place at the right time!*

THE WILLING-AND-ABLE-TO-BUY METALS INDUSTRIES MEN "SHOP THE SHOW" FOR IDEAS, TOO!

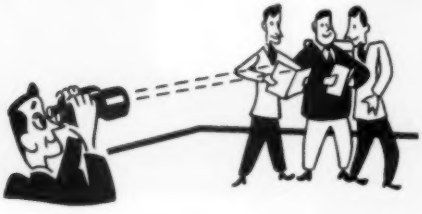
Part of the zest and spirit of the Big Metal Show lies in the competitive battle for attention by exhibitors proudly eager to prove what their individual products or processes will do for the visitors. And just as eager are the metal engineers who come to the Big Metal Show. They come to see . . . to learn . . . to study and adapt to their own problems the hundred-and-one new ideas they observe. *They buy—not only AT the Show, but months afterwards* —the things that interest them, that provide the spark that starts a chain-reaction of ideas churning. That's why this big, powerful "market" of metals industries men who attend the Big Metal Show is so important, so vital to every exhibitor. It makes sense, doesn't it, to back up your space dollar with program advertising to get your share of attention . . . for planning right now to make your product advertising point up the feature of the last quarter . . . the Big Metal Show? Certainly it does. The amazing thing is that so few ad managers seem to realize the whopping boat they're missing by not promoting customer attendance. Some do—and they reap mighty sweet sales harvests, too!

Metal Show in years! Philadelphia, Oct. 20-24

EXECUTIVES ARE LEARNING IT PAYS TO HAVE THEIR ENGINEERING, METALLURGICAL AND PRODUCTION STAFF MEN "COVER" THE BIG METAL SHOW!

Too often the key men of industry are so completely absorbed in the day-to-day, never-ending problems of their own plants and products that the broad, shifting markets and the competitive moves made to meet the needs of these markets are lost upon them. No man can develop vision . . . or ideas . . . or new markets if he doesn't lift his eyes from his work-stacked desk now and then . . .

Many executives are beginning to understand the need for free time . . . for thinking and dreaming time . . . among their staff men. How to put that free time to best use is quite a problem, because that time ought to be used in specific areas where trained minds and skilled hands could and should find challenging and provocative fields.



What better place than the big, enlightening, extremely competitive Metal Show? Last year a crew of trained observers studied the men who exhibited products, the men who came to see what was new and different. The results proved that men visited the Show with special ideas on their minds . . . special, that is, until they got into the Big Show. Then a lot of things happened to them. Metal engineers found a wealth of daring, different uses of metals . . . designers found idea-sparking twists to old traditions . . . production men saw and gloated over new machines . . . techniques . . . methods. Even the top brass found sales and marketing, as well as service, angles that opened their eyes.

Do this NOW . . . choose the men on your staff who OUGHT to attend!

The best investment you can make in the time and talents of your staff men is full-coverage of the Big Metal Show in Philadelphia this Fall. Pick the men right now . . . alert them . . . tell them you're sending them to the Big Metal Show because you want them to absorb what they see . . . to pick up new ideas . . . to check on everything that even looks like it might work for you! It can't cost you much . . . but *it can pay off big in new horizons and new vigor among your men!*

DO YOU HAVE *tough* X-RAY INSPECTION JOBS?

At the American Steel Foundries' plant in Newark, New Jersey, heavy steel castings are easily X-rayed due to equipment *flexibility*.

1 – *Constant Potential* high voltage generator produces more X-rays per KV than any other X-ray generator and does it over the range of 30-250 KV.

RESULTS – Materials from less than 1/8" aluminum to 4" of steel can be radiographed in less time.

2 – Jib crane tubestand carries the X-ray tubehead 6' vertically above a minimum 33" target-floor distance and 10' horizontally while moving approximately 270° around the vertical column. Additional beam angulation and tube positioning features are built into tubehead mount. A small hoist may be added to aid in positioning the part.

RESULTS – Time kept to a minimum for positioning the tubehead over the parts despite their size or position.

With Westinghouse you have the assurance of a coast-to-coast staff that provides the best technical service and advice. Call your Westinghouse representative, or write to Westinghouse Electric Corporation, 2519 Wilkens Avenue, Baltimore 3, Maryland.

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AXLE SPINDLES

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Foundrymen Discuss Shell Molding and Ductile Iron

(Continued from p. 95)

ship of certain patent rights. At the Norfolk conference, K. D. Mills of that organization defined the metal as "ductile iron containing spheroidal or spherulitic graphite". The International Nickel Co. purposely avoids the word "nodular", since conventional malleable iron has also been called "nodular", and the spheroids of graphite in the new material differ markedly from the areas of graphite in malleable iron.

In the 18 months since the matter has been promoted, some 75 foundries have been licensed in North America and another 25 abroad. Present interest may be gaged from the 11 papers on the subject presented at Atlantic City.

In simplest terms, 0.06 to 0.08% magnesium is added as magnesium-nickel alloy to molten white iron, low in sulphur, and the metal solidifies with pearlitic or ferritic matrix containing well-distributed nodules of graphite. Four grades are produced, with the properties shown in the tabulation below.

It was pointed out that the microstructure should be advantageous for pressure castings. Regular iron pipe of 12 in. diameter has wall strength between 26,000 and 33,000 psi. with no elongation. Ductile iron pipe, on the other hand, has from 70,000 to 94,000 psi. tensile strength with elongation running between 2½ and 8%. Hydrostatic tests to destruction result not in shattering but definite bulging before breaking. (It is well to remember that elongation is not necessarily a function of toughness or shock resistance. Some ductile iron, as other material, can be bent slowly in a machine but can also readily be fractured by a hammer blow.)

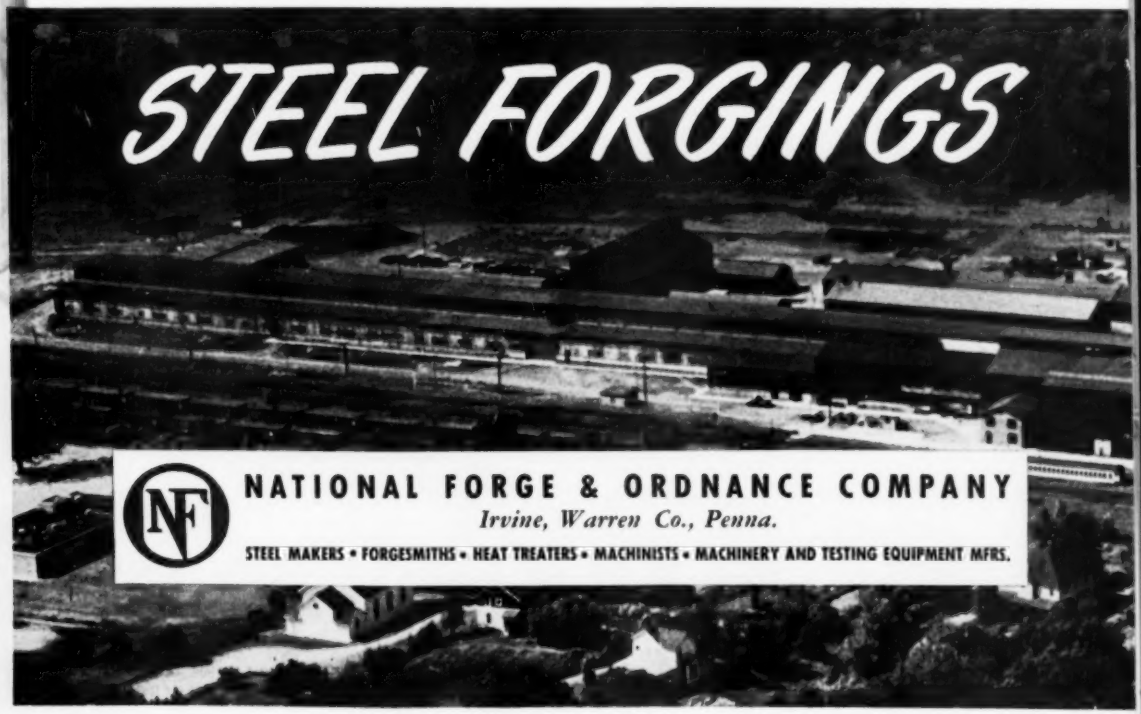
An excellent paper was read by H. Morrogh of the British Cast Iron Research Assoc. of Birmingham, England (the A.F.S. gold medalist for his services in connection with this development). Discussing the "Influence of Some Residual Elements and Their Neutralization in Magnesium-Treated Nodular Cast Iron", he said that very small amounts of lead, bismuth, antimony, titanium and aluminum inhibit the formation of nodular graphite. On the other hand, arsenic up to 0.09% and tin up to 0.01% do not have a harmful effect; they do, however, increase the amount of pearlite in the structure at the expense of ferrite. British experiments indicate that a very small amount of cerium neutralizes the harmful effects of the above residual elements. The cerium may be added to the molten iron prior to, simultaneously with, or subsequent to the addition of magnesium. A convenient alloy contains 10 to 18% magnesium, 0.5 to 3.0% cerium, balance nickel. The use of cerium thus enlarges the range of raw material that is available for the process.

	Grade A (As-Cast)	Grade B (As-Cast)	Grade C (Annealed)	Grade D★ (As-Cast)
Yield (max.)	75,000 psi.	70,000 psi.	60,000 psi.	75,000 psi.
Tensile strength	95 to 105,000	85 to 95,000	65 to 75,000	85 to 95,000
Elongation (max.)	5.5%	10.0%	23%	3.0%
Brinell hardness	265	225	180	290

★High manganese and phosphorus.

Basic-Lined Cupola

In the discussion of the various papers on ductile iron it was evident that this material has greatly stimulated the operation of basic cupolas. The basic lining and slag give the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desirable higher carbon content in the metal, and the sulphur is kept down to 0.03 to 0.04% without difficulty. Another feature of basic operation is that it reverses the acceptable ratio of steel to pig iron in the charge — sometimes all the pig iron may be replaced by steel scrap.

Many of the ideas contained in the paper by Sam F. Carter were summarized in "Critical Points" in last month's *Metal Progress*. They were generally approved by Walle Levi, chief metallurgist of the Lynchburg Foundry Co., where a basic-lined, water-cooled cupola with hot blast successfully made low-sulphur, high-carbon irons from a charge of 100% steel. These are well suited for modification into ductile iron and they can also be poured directly into castings where high-carbon irons are desired. A combination of magnesite and carbon brick was found to overcome taphole difficulties.

M. W. Demmler of Harbison-Walker Refractories Co., Pittsburgh, said that hard burned magnesite brick (88% MgO) are quite suitable for basic linings, although a new periclase refractory containing 92% MgO is superior for tap holes and for lining the troughs of front-slagging cupolas. High-fired chrome-magnesite refractories are being used for the breast as well as for slag-hole construction on a rear-slagging cupola. The newest type of basic refractory is forsterite ($2\,MgO \cdot SiO_2$) which contains 57% magnesia and 42% silica, and is characterized by unusually high strength under load at high operating temperatures.

On account of the high heat conductivity of basic refractories it is recommended that a course of fireclay be placed between the lining and shell.

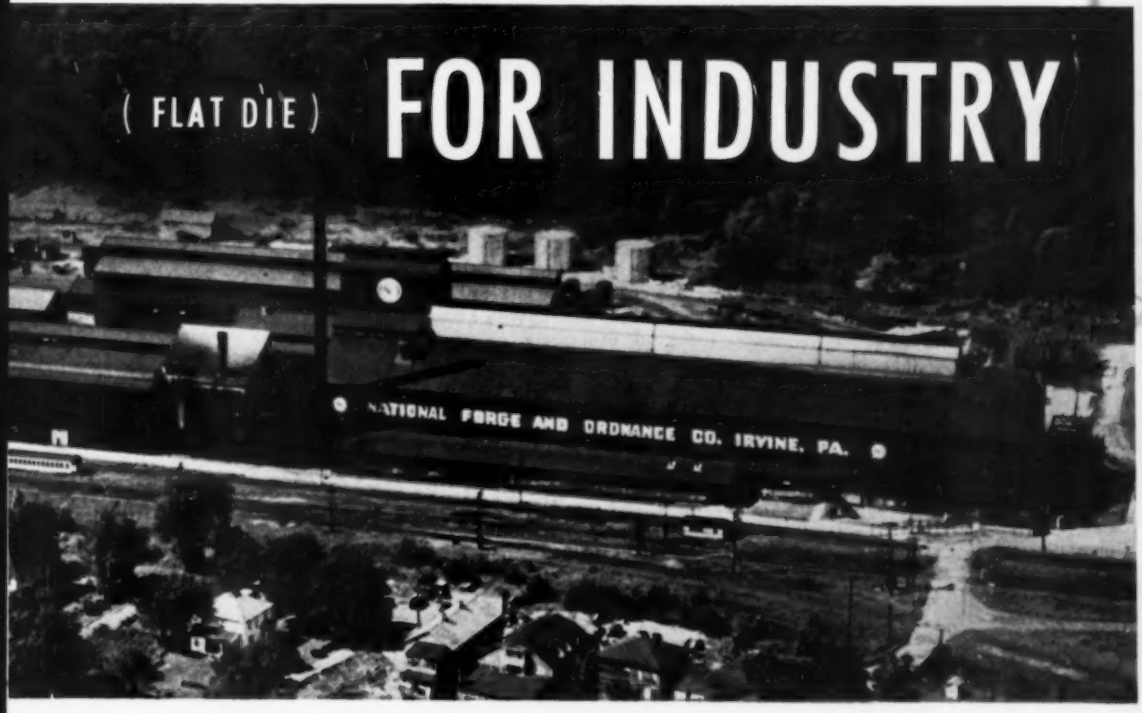
Mr. Carter brought out the interesting fact that a well-made basic lining would operate almost indefinitely if dolomite is gunned onto the eroded faces of magnesite brick.

THE EXPOSITION

As one walks around the exhibits and listens to the papers he realizes the only way of getting a satisfactory picture of the event is to ration his time. In fact, one man has not enough time or energy to assimilate the information provided. This holds true of the Congress and Exposition of many engineering or technical associations. Large companies should therefore have several representatives in attendance so as to get a really good coverage of lectures and exhibits.

Among the numerous exhibits of cleaning equipment, melting furnaces, molding equipment, and other practical helps to the modern foundryman was one that harks back some 500 years to the days of one of the most remarkable men history has produced, Leonardo Da Vinci, Italian painter, sculptor, architect and engineer. This exhibit of the Institute of British Foundrymen presented an old-world atmosphere strangely at variance with the rush and clatter of modern industrial life. Here quiet prevailed; on display were beautiful models of devices suggested by Da Vinci 450 years ago — machine guns, shrapnel, a mechanical car, a flying machine, roller bearings, an embryonic automobile jack, aerial bombs, a ship with a protective double hull, a revolving theatrical stage — all items that we have looked upon as creations of much more recent times. It is hard to associate a man who forecast so much in the engineering field with the painter of Mona Lisa and The Last Supper.

Here was a man!



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Testing Cemented Carbides

(Continued from p. 128)

rect hardness readings which will be lower than the true carbide material hardness. The test is considered nondestructive, because the piece may be returned to active use. The preparation for the microscope is prescribed, and this involves no extensive effort.

The X-ray diffraction spectrometer is a nondestructive test permitting the separation of steel cutting grades from nonsteel cutting grades, wear resistant grades, and shock resistant grades by means of the distinctive diffraction patterns for the different carbides.

The test methods most relied on by carbide tool users and fabricators are hardness, specific gravity, X-ray diffraction and metallographic. These examinations will indicate to a practiced observer any serious deviation from standard manufacturing technique.

The development of additional reference standards and methods of examination is a prime necessity for carbide tool makers and users.

Source of Hydrogen in Porcelain-Enameled Steel*

A RECENT study by the Enameled Metals Section of the National Bureau of Standards, using a tracer technique with heavy water, has at last fixed with certainty the role of hydrogen in causing both "fish-scaling" and reboiling in vitreous enamel on steel, and in identifying the sources of the gas in their order of importance.

Deuterium — which is ordinary hydrogen (protium) with a neutron in the nucleus — was introduced into the *(a)* pickling acid, *(b)* milling water, *(c)* quenching water, *(d)* chemically combined water in the clay, and *(e)* dissolved water in the frit.

In all tests conducted, the deuterium was added as "heavy water", in the first three simply by substituting D_2O for H_2O, and in the last two by dehydrating the material and then rehydrating it with D_2O. Gas evolving after cooling, whose effects are commonly noticed as "fish-

(Continued on p. 150)

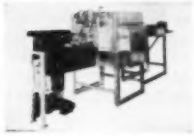
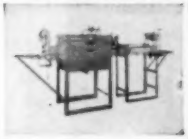
*Abstract of "Relative Importance of Various Sources of Defect-Producing Hydrogen Introduced Into Steel During the Application of Porcelain Enamels", by D. G. Moore, M. A. Mason and W. N. Harrison, *Journal*, American Ceramic Society, Vol. 35, Feb. 1, 1952, p. 33-41.

PROPER

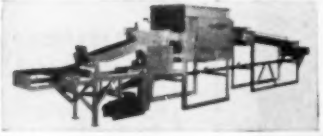
ELECTRIC CERTAIN CURTAIN FURNACES

HARDENING and TEMPERING

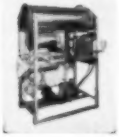
SINTERING and ANNEALING

COPPER BRAZING and SOLDERING



BRIGHT HARDENING & STAINLESS ANNEALING



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Source of Hydrogen in Porcelain-Enameled Steel

(Continued from p. 148)

scaling", "chipping" or "lifting", was collected and analyzed with a mass spectrometer, which readily differentiates D_2 from H_2.

Slight effects were found for the first four sources, but the effect of dissolved water in the frit swamped all others in importance. This research answers the several questions which have been outstanding in the industry, principally in the way of placing final approval on the earlier hydrogen theories which had postulated this gas to be the primary cause of both chip-type and bubble-type defects. The study also establishes that the principal source of the gas is the steam – metal reaction during firing. The authors find that both "fishscaling" and "lifting" are hydrogen-caused defects, and that "reboiling" is so closely identified with the same functions that their results would have been essentially the same if based upon reboiling criteria.

C. A. ZAPFFE

Transformations in Copper Alloys*

IN A RESEARCH sponsored in France by the Centre National de la Recherche Scientifique, it was sought to demonstrate the effect of allotropic transformations on the elastic modulus and logarithmic decrement of copper alloys. To determine these two properties, a specimen was subjected to forced longitudinal vibrations of small amplitude and high frequency under reduced pressure. The formation of body-centered cubic phases on heating eutectoid copper-aluminum and copper-tin alloys results in a marked decrease in the elastic modulus, while the logarithmic decrement assumes large values before and during the transformation.

The change in elastic modulus can be attributed to the disappearance of the γ-type phase and its replacement at high temperatures by the β-type phase whose modulus obeys the law of mixtures. It has been possible to confirm this explanation for copper-aluminum alloys but not for copper-tin alloys, owing

(Continued on p. 152)

*Abstract of "Thermoelastic Analysis of Transformations in Copper Alloys", by R. Cabarat, P. Gence, L. Guillet and R. Le Roux, *Journal* of the Institute of Metals, Vol. 80, 1951-52.

WHY IT PAYS

to reclaim worn forging dies with "HASTELLOY" Alloy C

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Besides eliminating the total loss of scrapping a worn forging die, rebuilding dies with HASTELLOY alloy C frequently makes them last longer than new ones. Most shops have found that repaired dies last 2 to 3 times longer than the original metal. Also, when a reclaimed die finally does wear, it can be machined and faced again.

HASTELLOY Alloy C Is Easy To Apply:

Alloy C rod can be easily applied to the worn contour and part lines of old forging dies. Preheating is seldom necessary except to speed welding of very large dies. The rod can be applied to any of the common die steels by arc welding.

Deposits Are Machinable:

When deposited, HASTELLOY alloy C has a hardness of about 200 Brinell. It can be machined by any of the common diesinking tools. Grinding is not necessary.

Peening Is Eliminated:

There is no need to peen or hammer a HASTELLOY alloy C deposit. Deposits work-harden in service to from 325 to 375 Brinell and have excellent resistance to chipping and spalling.

For further information on rebuilding worn forging dies, get in touch with the nearest Haynes Stellite Company district office. Ask for a copy of the new "Haynes Hard-Facing Manual," which tells how to apply HASTELLOY alloy C and many other HAYNES hard-facing rods.

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Transformations in Copper Alloys

(Continued from p. 150)

to the low melting point of tin. However, at 1110° F., the modulus of the body-centered cubic phase in the copper-tin system lies on the straight line joining the modulus of copper and that of the ε phase (corresponding closely to Cu_3Sn) at this temperature. At room temperature, the modulus of ε obeys the law of mixtures.

As regards the hypo-eutectoid alloy containing 20.2% tin, if the change in the modulus on passing through the transformation point is less marked, this is because the alloy contains an excess of α which does not take part in the transformation. Above the transformation temperature the modulus remains higher than that of the alloy containing 24.9% tin, since the α phase in it, being less rich in tin, has a greater modulus. It is known that the decrease in the elastic modulus of copper alloys is roughly proportional to the content of added element in the region of the face and body-centered cubic phases.

The results for the logarithmic decrement are particularly interesting. From the high values obtained and the frequencies employed, it appears that the internal friction is due, for the most part, to irreversible phenomena initiated by the vibrations. The dislocations set up in the crystals may be caused by the transformation or by the process of preparation for it; they may also be in existence before the transformation begins.

The behavior of the copper-aluminum alloy, in which the transformation is considered to be isothermal and the constitution of which undergoes no change before reaching 1050° F., is especially significant, for if the logarithmic decrement attains considerable value before reaching this temperature, it means that the isothermal transformation is preceded by a period of preparation, a phenomenon that appears to be revealed only by so sensitive a property as the internal friction. The same applies to the alloy containing 32.5% tin, consisting solely of δ. It is during the isothermal transformation itself that the decrement passes through a maximum, and this indicates that the instability of the lattice structure is the cause of an energy loss which ends when transformation is complete because the state is then more stable.

TOM BISHOP

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PROBLEM: to uniformly heat the entire surface of octagonal wheel blanks . . . to a rolling temperature of 2050° F. Blank is rolled, from hub to rim, in a series of passes, without reheating, to finish as a uniformly tapered blank. Uneven taper would result in an unbalanced wheel.

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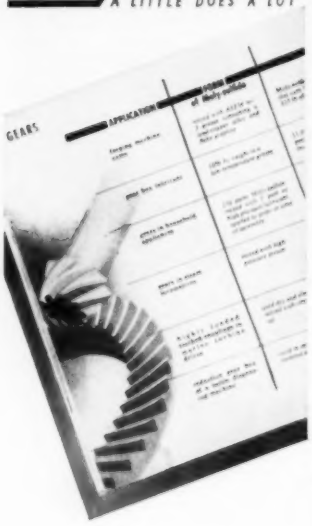

Moly-sulfide, a solid film lubricant, stands out most where the lubricating conditions are the most difficult. If you have to contend with extreme conditions of pressure, temperature, fretting, or velocity, you should try ***Moly-sulfide***. First write for a copy of this free 40-page booklet which shows where the above conditions have already been overcome in the shop and in the field.

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Furnace Flames and Efficiency*

LACK OF INFORMATION regarding the radiation from luminous flames has led to the formation of an international research organization, with scientists from France, Great Britain, Holland and Sweden being engaged in the work. The investigation reported in this paper was devoted to performance trials to obtain information on the relation between the flame and its surroundings, and to combustion mechanism trials to reveal what actually happens as the fuel burns.

The furnace used in these investigations (built of fireclay brick at the Royal Netherlands Steel Co., Ijmuiden, Holland) measures 24½ ft. long, 6½ ft. wide, 6½ ft. high, and has an 8-in. lift in the center. The brickwork is designed to give an evenly distributed air flow at the beginning of the flame. A refractory baffle at the farther end of the furnace forces the waste gases through a narrow opening to give a horizontal flame and reduce the effect of external wind conditions. The furnace has slots and holes for the insertion of probes and sighting of instruments.

The work in the first year was directed to performance trials in which five variables were studied, each on two levels, by a factorial method. These variables were quantity and type of fuel, quantity and type of atomizing agent, and quantity of combustion air. Detailed results of these forty-eight trials were given recently in the *Journal* of the Institute of Fuel. The measurements taken included vertical traverses with mirror-type radiation pyrometers, readings with probe and wall heat-flow meters, a gas sample traverse at the baffle, measurements of flame contour and optical pyrometer readings of flame temperature at all possible points. Intention of the trials was not only to reveal the effect of changes in these variables, but also to give information on the development of suitable instruments for this and industrial furnaces. Several new instruments were designed for this research work.

Because the number of variables was large, the results were analyzed statistically and the following indications were obtained. The time or

(Continued on p. 156)

*Abstract of "Flame Radiation and Furnace Efficiency", by Max Davies, *Murex Review*, Vol. 1, No. 10, 1952.

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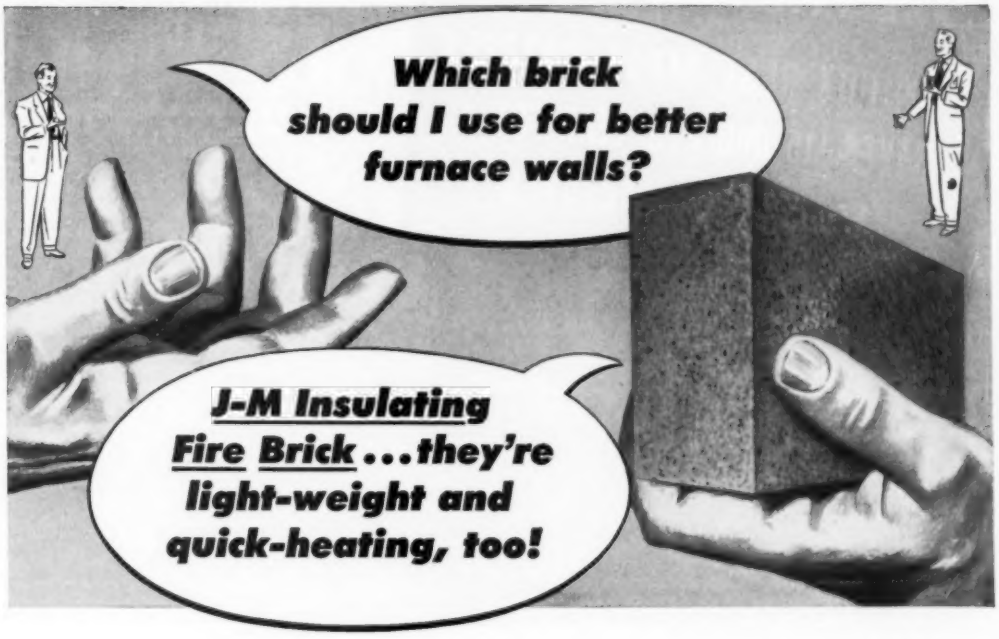

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A Johns-Manville insulation expert will gladly explain the advantages and economies of using J-M Insulating Fire Brick and Fireblok for refractory linings or as back-up insulation behind other refractory protection. Write to Johns-Manville, Box 60, New York 16, N. Y. In Canada, write 199 Bay St., Toronto 1, Ontario.

Properties	Types of Insulating Fire Brick and Fireblok					
	JM-3000	JM-28	JM-26	JM-23	JM-20	JM-1620
Temperature limit	†3000F	†2800F	†2600F	†2300F	†2000F	‡2000F †1600F
Density, lb per cu ft	63—67	58	48	42	35	29
Transverse strength, psi	130	120	125	120	80	60
Cold crushing strength, psi	400	150	190	170	115	70
Linear shrinkage, percent	*0.8 at 3000F	4.0 at 2800F	1.0 at 2600F	0.3 at 2300F	0.0 at 2000F	0.0 at 2000F
Reversible thermal expansion, percent	0.5—0.6 at 2000F	0.5—0.6 at 2000F	0.5—0.6 at 2000F	0.5—0.6 at 2000F	0.5—0.6 at 2000F	0.5—0.6 at 2000F
Conductivity (Btu in. per sq ft per F per hr at following mean temperatures)						
500F	3.10	2.00	1.92	1.51	0.97	0.77
1000F	3.20	2.50	2.22	1.91	1.22	1.02
1500F	3.35	3.00	2.52	2.31	1.47	1.27
2000F	3.60	3.50	2.82	2.70	....	....

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CAUTION . . . Only Nox-Rust makes the exclusive new Vapor-Wrapper that's impregnated with Cellex . . . the patented VOLATILE CORROSION INHIBITOR. (U. S. Patents 2,521,311—2,534,201—other patents pending).

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City_____ State_____

Furnace Flames and Efficiency

(Continued from p. 154)

distance of travel of a flame from the burner has a primary influence on the emissivity of an oil flame. In general, the emissivity is unity up to 6½ ft. from the burner, 0.5 at 13 ft., and probably reaches calcuable nonluminous emissivity at 16 or 18 ft.

Measurements on the early part of the flame showed the heat radiation increased 13% for air atomization against steam, 20% for creosote pitch instead of fuel oil. Observation on the tail of the flame showed that an increase of 39% in the fuel gave an increase of 49% in the radiation 9½ ft. from the burner, a reduction of 25% of excess air gave an increase of 17%, and a decrease of 45% in the quantity of atomizing agent gave an increase of 13%.

Combustion mechanism trials have been started at Ijmuiden to study flame composition, carbon particle size and local flame characteristics. The first series of such trials has been completed and more are planned.

This work will be supplemented by Swedish experiments on the Lindmark furnace which is being reconstructed and will use the same fuels. In addition, a smaller furnace, 6 ft. long, is being constructed at Delft by Shell Petroleum Co. to study similar problems at reduced expense. Much of the laboratory work is being conducted at the physics laboratories of the British Iron and Steel Research Assoc.

J. B. WAGSTAFF

Oxygen Refining of Pig Iron*

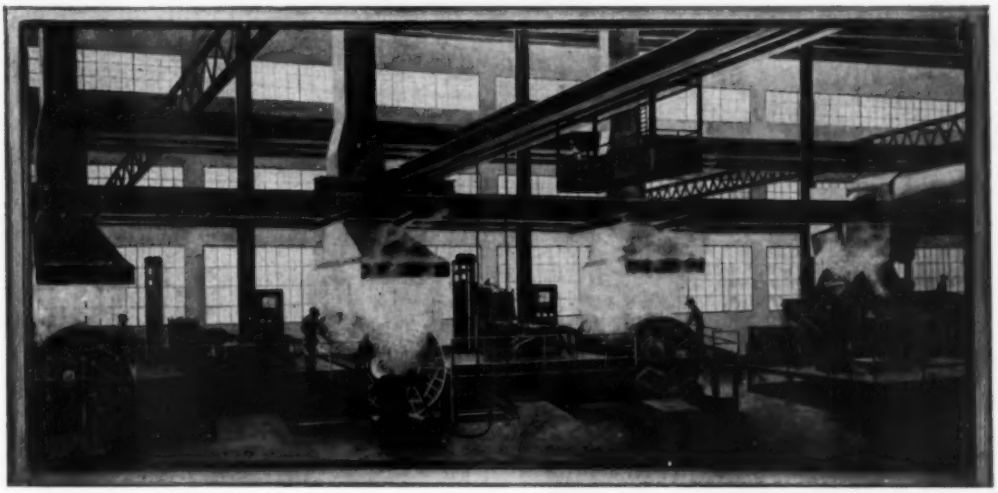
OXYGEN INJECTION refining of baths containing large amounts of pig iron was investigated to determine the method's possibilities for charges of 75 to 80% Thomas pig iron and 25 to 20% scrap. Three test series were run: *(a)* preliminary studies with charges containing 50% pig iron; *(b)* development of a technique usable with charges containing 75% pig iron; *(c)* confirmatory tests applying this technique.

The injection technique is de-

(Continued on p. 159)

*Abstract of "Refining of Phosphorus Pig Iron by Oxygen in the Openhearth Furnace", by G. Husson and P. Bettembourg, *Revue de Metallurgie*, Vol. 48, No. 2, 1951, p. 135-139.

AJAX Induction Melting Furnaces— A Modern Tool for Industry



This oil painting, 9 feet long in full color, by J. Gordon White, shows AJAX-SCOMET installation at Scovill Manufacturing Company, Waterbury, Connecticut

Here is a new tool for melting metal. . . . Something that can concentrate enormous power in a small space . . . . Something that can be adapted to accurate pouring, to precise temperature control, to inert gas protection, to high-grade refractories. . . . A tool that can be used for all existing non-ferrous metals and alloys.

AJAX furnaces paved the way for continuous casting processes which lay dormant in old patents of farsighted inventors who thought ahead of their times. Junghans, with the help of the AJAX furnace, developed his continuous casting process at the Wieland Works in Germany before the last World War.

Scovill perfected the Junghans process in this country and is using AJAX-SCOMET furnaces of unprecedented sizes for melting, as shown in painting above. Nichols Wire & Aluminum Company used the first commercial Properzi machine for continuous production of aluminum wire from molten metal delivered by AJAX furnaces; U. S. Metals Refining Company is using AJAX-SCOMET furnaces for continuous casting of oxygen-free copper. Cleveland Graphite Bronze Company produce their famous stock for steel backed copper-lead bearings exclusively in AJAX melting furnaces. Hunter Douglas Corporation, Riverside, California, uses AJAX furnaces for continuous casting of aluminum alloy strips for venetian blinds. AJAX furnaces are used in many plants and research laboratories for continuous bonding aluminum to steel.

AJAX made the first furnace for galvanizing steel in a refractory lining with accurate temperature control. AJAX furnaces were instrumental in the realization of modern squirrel-cage aluminum rotor production. AJAX supplied the first commercial automatic pouring device for die-casting machines.

These few examples show how AJAX induction furnaces can be applied to modern manufacturing methods. Write us for further information.

AJAX TAMA-WYATT

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AJAX ELECTRO METALLURGICAL CORP., and Associated Companies
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Oxygen Refining of Pig Iron

(Continued from p. 156)

scribed in detail. It suffices to say that two tubes were used to inject oxygen just below the slag-metal interface. The injection rate was about 24,700 cu.ft. per hr., each tube delivering half of this amount.

Four heats were run, charging 25 to 26 tons of scrap directly on the hearth with the lime being interspersed. After the scrap had settled, liquid (Thomas) pig iron was added in about 12-ton lots, the second lot being added one-half to one hour after the first. Average composition of the charge was 1.75% carbon and 0.9% phosphorus.

The most successful heat was charged using 2200 lb. of ore and 4½ tons of limestone. The first test after fusion showed 0.85% carbon and 0.14% phosphorus, with 10% FeO in the slag. Oxygen injection amounted to 7600 cu.ft., the lime addition being 9¾ tons. This lowered carbon to 0.45% and phosphorus to 0.028%, while iron oxide in the slag increased to 19%. Refining was finished by using ore; the heat was tapped at 0.24% carbon 6 hr. 20 min. after charging was started.

The procedure just described was used for the first charge containing 72% pig iron, carbon content being 2.5% and phosphorus content being 1.35%. Limestone was increased to 6 tons and ore was raised to 2½ tons. Pig iron was added from three ladles, the second and third at 35 to 40-min. intervals.

The results were poor, and after an additional trial, the following procedure was found to be efficient: Charge 6% lime and 4% ore between two layers of scrap, fire vigorously; add first ladle of liquid pig iron after forming an oxidized bath, then add remaining pig iron as rapidly as possible. After charging, start injecting oxygen, stop firing completely and, while injecting, add an additional 2.5% of lime. After injecting about 350 to 420 cu.ft. of oxygen per ton, the first slag was scraped off, this slag being high enough in phosphorus to constitute a Thomas slag (18 to 20% P_2O_5); another slag was remade with lime and ore, and refining was resumed using oxygen. Carbon removal was followed with a carbometer. At about 0.20% carbon, oxygen injection was stopped while refining continued in the normal manner, with

(Continued on next page)

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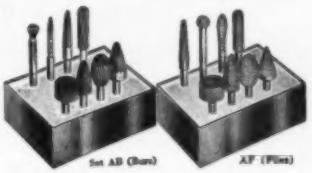

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Technical Service Data Sheet

Subject: HOW TO MAKE PAINT STICK TO GALVANIZED IRON WITH LITHOFORM®

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"Lithoform" forms a dense, zinc phosphate coating on zinc, cadmium, and galvanized surfaces—including Galvanneal, cadmium plated steel zinc plated steel, zinc base alloys, and zinc base die castings. The "Lithoform" coating, which is non-metallic and inactive, retards reaction between alkaline metal oxide and the paint film. Peeling and loss of adhesion are thus greatly retarded on painted Lithorized zinc and cadmium.

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"Lithoform" forms a durable bond for paint. It is economical. It eliminates frequent repainting. It protects both the paint finish and the metal underneath. "Lithoform" meets these Government Finish Specifications:

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MIL-E-917A (Ships)
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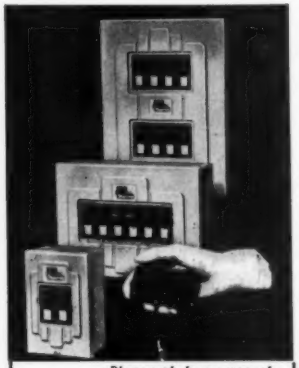

Photograph by courtesy of Murray Manufacturing Corp.

Murray Circuit Protectors are fully magnetic and provide maximum protection for both domestic and industrial wiring. Housings are of galvanized iron which is Spray Lithorized for long paint life.

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"Lithoform" can be applied by brushing or spraying the work with simple hand equipment, by dipping it in tanks, or by spraying it in industrial power washers.

Brush. Galvanized bay windows, cornices, rain gutters, hardware, building siding, truck panels, and farm equipment are typical of the many surfaces that are treated effectively with Brush "Lithoform".

Dip. This grade is used for coating cleaned surfaces of such typical products as cabinets, refrigeration condensers, etc., immersed in heated solutions in tanks.

Spray. The spray process is the most logical one with which to coat sheets, coiled strip or duplicate products best processed on a conveyor.

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Oxygen Refining of Pig Iron

(Continued from preceding page)

a second rake-off and formation of a third slag if necessary.

This formula permitted refining a 50-ton charge, containing 72% Thomas pig iron of 0.35% silicon in 5½ hr. from the start of charging to tapping, while consuming 700 cu.ft. of oxygen per ton. Two additional tests were unsuccessful, probably because the pig iron used contained about twice as much silicon.

The importance of this silicon variation is apparent from calculations. These show that for a 50-ton furnace, pig iron with 0.7% silicon will originally require a supplementary addition of ¾ ton of lime and almost as much ore (or 1100 lb. of scale). It is advisable to use scale to avoid adding any more silica; use of scale to remake the slag is also suggested.

Metal spitting and tube wear can be reduced by regulating oxygen delivery to about 12,350 cu.ft. per hr. per tube, meanwhile keeping the end of the tube a few inches below the surface of the liquid metal.

The annoyances caused by the red fumes should be mentioned. These fumes fill the furnace working chamber, making observation impossible, and they discharge from the stack as a thick cloud, which must have passed through the regenerators and probably caused damage. Compressed air injection was also used to start the refining operation. The first two heats were unsuccessful. Carbon removal was not accelerated, and several bad overflows occurred.

R. W. LINDSAY

Corrosion Data Surveyed in Chart Form*

TO EVALUATE the corrosive effect of 462 chemicals in varying concentrations on a series of 25 metals, alloys and nonmetallics was the herculean task undertaken by G. A. Nelson of Shell Development Co. The effort was made as a guide for screening of likely materials of construction, particularly in oil

(Continued on p. 162)

*Review of "Corrosion Data Survey", by G. A. Nelson. Second edition, 64 p., including 46 charts, 11 x 16 in., and accompanying preface, comments and discussion. Published by Shell Development Co., San Francisco, Cal., cloth bound, $35.00.

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JESSOP

STEEL COMPANY - WASHINGTON, PENNSYLVANIA

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Photo Courtesy Metal Control Laboratories

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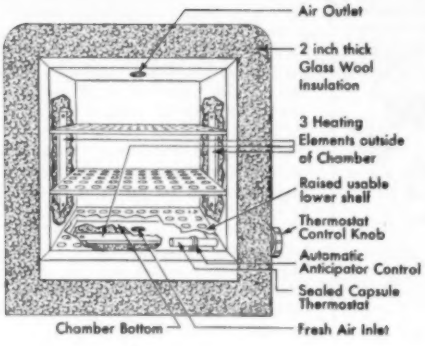

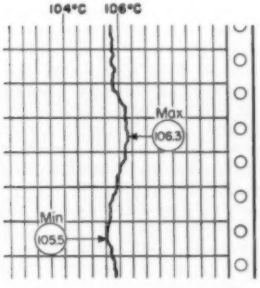

Temperature recorder chart of the oven shows the close control —within ± 0.5°C.

The Fisher Isotemp Oven is a well-constructed, gravity-convection oven that provides both constant temperatures and uniform heat distribution throughout the entire oven chamber. The temperature within the oven can be set for any degree within the range of 35° to 200° C. and a sensitive thermostat maintains the temperature of the oven chamber within ±0.50 C.

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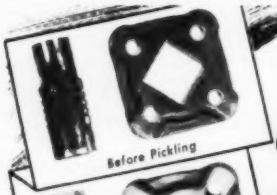

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CLEANERS • EQUIPMENT • METHODS

Corrosion Data

(Continued from p. 160)

and chemical plants. It is qualitative rather than quantitative and facilitates the quick determination of what materials are unsuitable in designing new construction.

Data are assembled in chart or graph form, relating each corrosive agent against each material, with concentration of the corrodent plotted horizontally at ten points from 10 to 100% and temperature plotted vertically at 75, 125, 175, 212, 300, 400, 500, 600, 700 and 800° F. Naturally, there are data available for only a relatively few of these coordinates. Corrosion rates are indicated by four symbols, one signifying a rate of less than 0.002 in. per year, a second less than 0.020 in. per year, a third from 0.020 to 0.050 in. per year, and the fourth greater than 0.050 in.

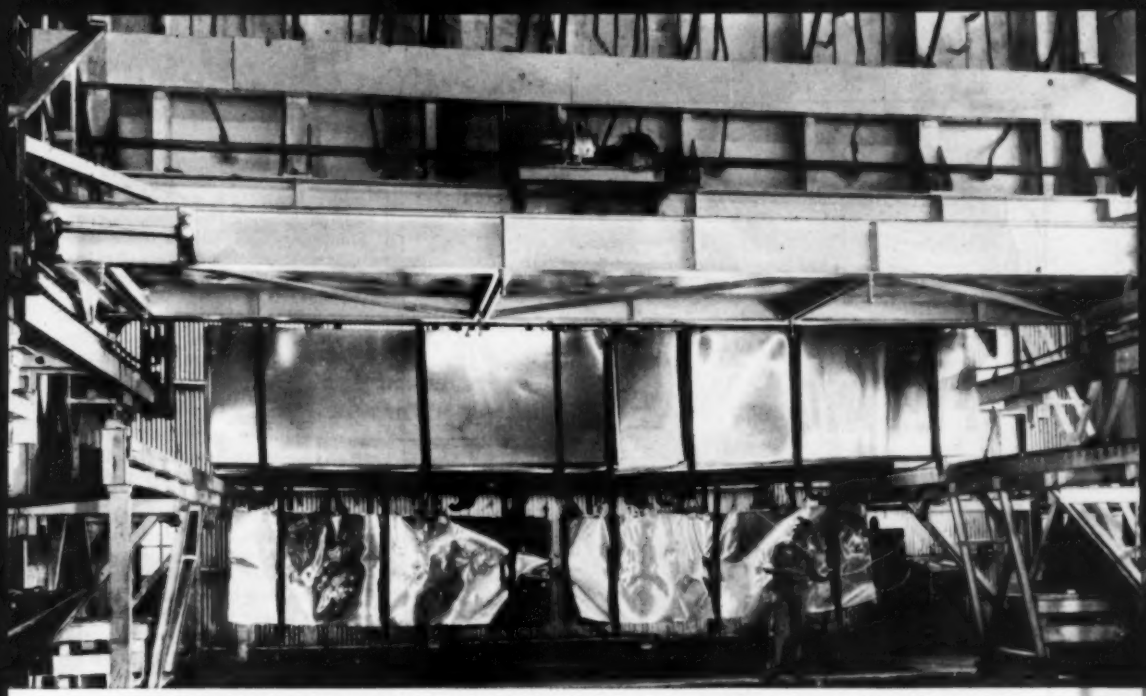
Information on the various rates of corrosion was obtained from a wide range of sources such as books, catalogs, magazines, research reports and data sheets. Among the more important references were the *Metals Handbook*, and the *Book of Stainless Steels* by E. E. Thum. Charts are of the fold-out type and each one lists 15 corrosive agents vertically, with the 25 materials carried across the page, each vertical column showing available data for a single material as it may be affected by the 15 corrodents.

Obviously there are factors other than concentration and temperature that influence corrosion rates. They include, to mention a few: Velocity, impurities in the corrosive, aeration, condition of the material surface and galvanic effects. These factors could not be easily charted but wherever important information has been available, notes are appended to the graphs.

Influences on corrosion arising from fabrication and pretreatment of materials also are noted on some of the charts. Stress relieving usually is specified for certain metals in corrosive service for prevention of stress-corrosion or stress-corrosion cracking near welds and bends. However, stress-corrosion cracking does not occur in all media and the author points out that when sufficient data are collected better heat treatment specifications may be made.

Basic group of materials considered is: Steel (low carbon), cast iron, Ni-Resist, copper (including tin and aluminum bronze), red brass, yellow brass, silicon bronze,

(Continued on p. 164)



ELEVATOR FURNACE NEARS 10 YEARS SERVICE OF CONSISTENT, ACCURATE TREATMENT OF HIGH-QUALITY ALLOY SHEET.

Reynolds Metals Co. Says "G-E Furnaces Meet Heavy Schedule, Need Few Repairs"

Their Listerhill, Alabama, plant is now operating at full capacity to meet the ever-increasing demand for aluminum. And to meet this high production schedule, Reynolds depends on many types of G-E electric furnaces for annealing, aging and solution heat-treating.

MR. M. A. J. PHILLIPS, Reynolds Vice-president, says, "We are very pleased with the dependable service our G-E furnaces give with little downtime." One of his engineers adds, "Uniform heat distribution is very important in aluminum heat-treating, and the consistent high-quality work our G-E furnaces turn out proves the importance of properly locating heating elements and designing the circulation equipment to fit the loads."

ALUMINUM FABRICATORS, as well as prime producers like Reynolds, can profit by using G-E furnaces for their heat-treating operations.

TAKE ADVANTAGE of G-E experience in heat-treating of aluminum. Call the nearest G-E sales office for the services and recommendations of their experienced Industrial Heating Specialist on your heat-treating problem. *General Electric Company, Schenectady, N.Y.* 720-82

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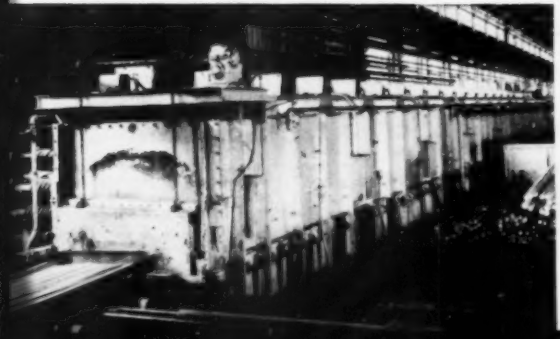
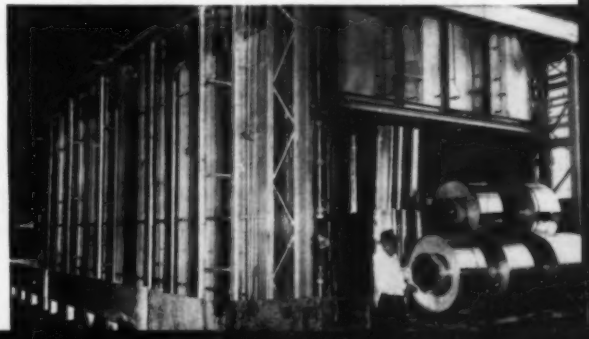
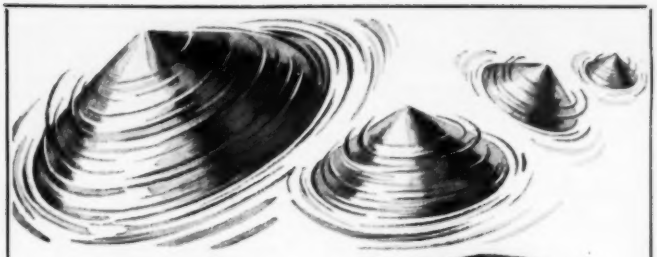
SEVEN DAYS A WEEK this roller-hearth furnace works around-the-clock to heat and spray-quench bars and rods at 950 F.



100 TONS PER CHARGE are annealed in this metal-lined truck furnace. Highest-quality stock results from uniform heating.





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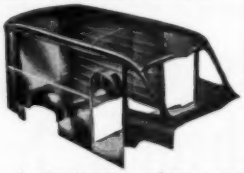
Place your order with Brandt . . . and save!



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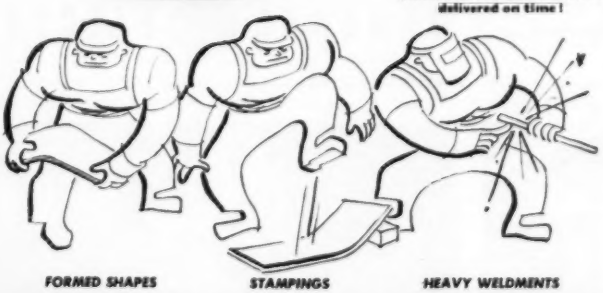

FORMED SHAPES *STAMPINGS* *HEAVY WELDMENTS*

CHARLES T. BRANDT, INC. BALTIMORE 30, MD.

Corrosion Data

(Continued from p. 162)

12% chromium steel, 17% chromium steel, 18-8 stainless, Monel, nickel, Inconel, Hastelloy, Durimet, aluminum, lead, silicon irons, glass and stoneware, rubber, asbestos, plastic and Karbate (impervious carbon).

Corrosive agents run the full gamut from common acids, alkalis and salts to the complex chemicals such as dichlorodifluoromethane and their polysyllabic counterparts.

A quick glance through the charts shows, as might be expected, that glass, stoneware and the silicon irons generally lead the list of materials in corrosion resistance to most reagents. It is not surprising that there are many items on the charts for which no data have been found to show a rating. However, it may be that if the volume proves to be as handy a reference as it appears, supporting information will eventually be forthcoming to fill in some of these gaps in the future.

In the author's closure are listed five types of information, representing the consensus of engineers concerned with corrosion problems, which are considered to be the most useful:

1. Corrosion information between room temperature and the boiling points.
2. A precise definition of those materials which are practically inert to the particular corrosive agent.
3. Information regarding additional effects which might be created by factors such as aeration, impurities, velocity, and such.
4. Surface condition of the material before contacting the corrodent.
5. Interior structure of metal which will produce the best resistance to the corrodent.

A. H. Allen

New Source of Radiation*

One of the early and most valuable achievements of the U. S. Atomic Energy Commission — other than for weapons — was the production of considerable quantities of radioactive cobalt, Co^{60}, at such a low cost that it was put to immediate use as a substitute for radium and high-intensity X-rays, not only for treatment of deep cancers but

(Continued on p. 166)

*Abstract from "Plan to Develop Cesium Teletherapy Unit Supported by Council Committee, Board", *News Letter*, Oak Ridge Institute of Nuclear Studies, Vol. 4, April 1952, p. 2.

When your eye is on Pittsburgh—and three dozen towns in its orbit—you're spotting scores of furnace operations regularly checked by Cities Service Heat Provers. Here, where they know all kinds of furnace instruments, and where high efficiency is most urgent today, the application of Heat Provers by Cities Service is increasingly valued.

It takes the Heat Prover to read simultaneously for oxygen and combustibles, measured direct by actual gas analysis. And the Heat Prover's continuous rapid sampling reveals effects of furnace adjustments at once. The Heat Prover frees you of maintenance too, because it's *not an instrument you buy, but a Service we supply*. Learn how it can raise productivity for you . . . in iron, steel, ceramics, glass, cement or any other furnace operation. Write CITIES SERVICE OIL COMPANY, Dept. G-0, Sixty Wall Tower, New York City 5.

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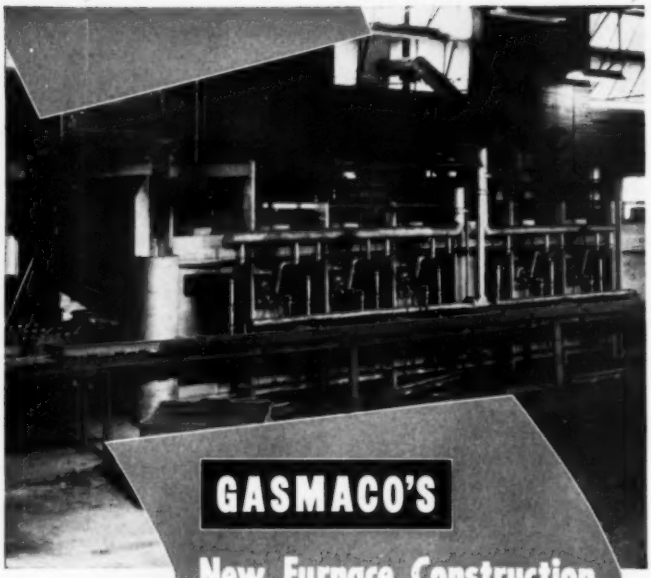

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Specifications for forging and heat treating can be met by employment of a rotary furnace, the construction of which requires only refractory and moderate quantities of carbon steel. Rotary furnaces require less investment for the same duty, and results are superior.

Other Gasmaco accomplishments include the use of silicon carbide in roller hearth furnaces, replacing alloy steel. For practically all applications where alloy steel tubes and rollers were formerly used, silicon carbide can be substituted, with greater benefit.

Our furnace engineers will be glad to point out the many advantages of Gasmaco developments and industrial heat applications which may fit your requirements.

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New Source of Radiation

(Continued from p. 164)

also for radiographic examination of materials for subsurface defects. Arrangements have now been made by the Oak Ridge Institute of Nuclear Studies for the intensive investigation of the therapeutic effects of cesium^{137}, which comprises about 6% of the waste material (fission products) that must periodically be eliminated from a chain reactor using natural uranium as fuel. The quantity available is therefore almost unlimited. Cobalt^{60}, on the other hand, is produced by irradiation of natural cobalt in nuclear reactors of high neutron flux, and its amount is limited by time and available space in existing reactors.

The half life of Cs^{137} is 33 years, while that of Co^{60} is 5.3 years, so that a cobalt source must be replaced six times as often as a cesium source. On the other hand a 1000-curie source of Co^{60} yields three times the gamma rays, in terms of roentgens, and of double the energy. Both beams are monoenergetic, in contrast with the varying wave lengths coming from an X-ray machine. It is anticipated that a shielded unit of Cs^{137}, equivalent in radiation to a million-volt X-ray unit and requiring no electrical controls whatever, can be produced so cheaply that deep radiation therapy can be within the financial and operating range of every practical radiologist.

E. E. T.

Low-Temperature Embrittlement of Welds*

THE AUTHORS have rounded out their previous published works on low-temperature cooling rate embrittlement by reporting in this paper the results of tensile, fatigue and impact tests of similarly embrittled welds, and comparing them with the previous results from notch bend tests; conclusions are drawn from the data as a whole. The steel was ¾-in. plate from the same heat used in the previous tests. All welding was carried out with manual electrodes of the E6010 and E6016 types. The effect of testing temperature and the detection, appearance and distribution of microcracks are discussed.

(Continued on p. 168)

*Abstract of "Microcracks and Low-Temperature Cooling Rate Embrittlement of Welds", by A. E. Flanigan and M. Kaufman, *Welding Research Supplement*, Vol. 30, December 1951, p. 613-622.

For this Automobile Fan Shaft . . .

The right Republic Steel Saved

40% IN COST...

3 OPERATIONS...

3 INSPECTIONS...

AND 1 BIG HEADACHE

Here's another case where Republic Carbon-Corrected Bar Stock replaced a carburizing steel.

Before they switched to Republic Carbon-Corrected Steel Bar Stock for automobile fan shafts, Schwitzer-Cummins Company had been carburizing the steel shafts after machining. This ran up costs, created the headache of carburizing and inspecting, tempering and inspecting, cleaning and inspecting, and finally straightening warped shafts and inspecting.

The Schwitzer-Cummins metallurgist called on our Republic 3-Dimension Metallurgical team . . . the Field Metallurgist, backed up at home by the Laboratory and Mill Metallurgists. The decision was made to change over to Republic Carbon-Corrected AISI-C 1144 Bars. Now, induction hardening and inspection takes the place of the previous 8-step procedure. No warped shafts to straighten, and a better fan shaft that will last longer in your car or truck. Cost is reduced up to 40%.

The help our Republic 3-Dimension Metallurgical Service gave to Schwitzer-Cummins metallurgists is also available to you. It can help you make better products at lower cost. When shall we call?

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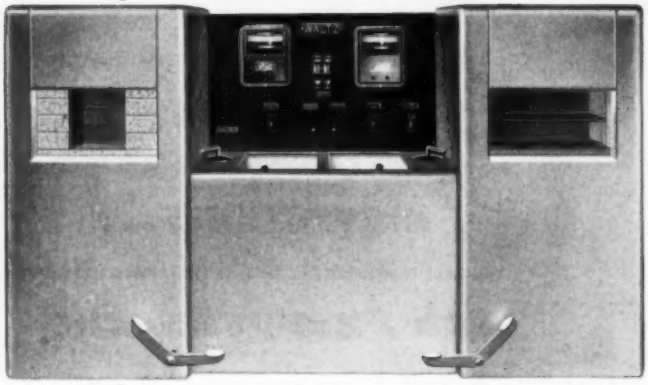
Waltz gives you a complete heat-treating department



in a single unit

Waltz CH gas fired heat-treating unit gives you all the advantages of a full scale heat-treating department. Designed for heat-treating all types of oil or water hardening steel . . . for heating, quenching and drawing . . . for stress relieving, normalizing and annealing, with controlled atmospheres.

Features include:

1. *Heating Furnace with range of 1000° to 2400° F. automatically controlled (12" wide x 10" high x 18" deep).*
2. *Tempering or Drawing Oven is recirculating type. Work is constantly bathed with evenly distributed high velocity and held to constant temperature by automatic control. Alloy steel lined with perforated shelf, has range of 250° to 1100° F. (21" wide x 10" high x 18" deep).*
3. *Furnace and Oven doors equipped with foot treadles.*
4. *Two Quench Tanks for oil and water. By means of double wall construction, oil tank is entirely surrounded by water for cooling oil, thus producing more uniform quenching.*
5. *Automatic electronic type controls.*
6. *Shipped ready to install by simply connecting gas and electric power line.*

A complete line of WALTZ standard or special heat-treating furnaces, using all types of fuels are built to suit your requirements. Write for comprehensive illustrated bulletins.

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CINCINNATI, OHIO

Low-Temperature Embrittlement of Welds

(Continued from p. 166)

Bend Tests — The notched bend specimen consisted of a centrally placed weld bead on a ¾ x 4 x 9-in. plate with a center transverse U-shaped groove of ⅛-in. radius cut across the entire width of the specimen to a depth of 0.020 in. Tests were carried out four days after welding. The notch bend tests reported previously were carried out at −100° F. To determine the effect of testing temperature, certain of the tests were repeated at 70° F. It was found, in general, that the indications of embrittlement were nearly as severe as had been noted at −100° F. In the tests at −100° F., complete and abrupt fracture of the specimens was precipitated by the first cracking of the weld. In the room-temperature test, the first sizable crack (or the growth of a crack entirely across the weld) was taken as the criterion of weld failure.

The performance of fissured welds was not greatly benefited by postheating up to 1650° F. What benefit there was appears to have been associated with the weld metal's resistance to crack propagation rather than its ability to resist crack initiation.

Tensile Tests — The 9-in. welding bead was deposited on the longitudinal center line of a ¾ x 4 x 18-in. blank, the test section being milled to a 2-in. width after welding. The weld crown was not removed. Tests were made of E6010 and E6016 welds in the air cooled and water quenched (70° F.) conditions, the same conditions for E6010 after postheating for 3 hr. at 1150° F. (air cooled), and of E6010 welds laid down on plates cooled to −100° F. in a box chilled by dry ice and replaced into the box following welding.

The results of the nonpostheated E6010 weld tensile tests clearly indicate the embrittling influence of microcracks under conditions of direct tensile loading. Both groups of postheated E6010 welds benefited from the treatment. The results of the water quenched, postheated weld tests were not as good as the air cooled welds. The results of the water quenched E6016 weld tests were not inferior to the air cooled welds.

It is of interest to note that in the air cooled, postheated E6010 welds, and both groups of E6016 welds, the fracture was instantane-

(Continued on p. 170)

Tool Steel Topics

A-H5... air-hardening and easy to machine

Toolmakers rely on air-hardening tool steels to reduce the chances of cracking tools and dies during hardening. These steels are also preferred when only the minimum amount of distortion in heat-treatment can be tolerated. Air-hardening steels are deep-hardening, and have the high percentage of carbides that is so necessary for long wear.

From the toolmaker's standpoint, the principal objection to some air-hardening grades is their poorer machinability as compared with low-alloy tool steels. And that's why A-H5 is such a popular steel. It offers all the desirable properties of air-hardening steels, yet it can be annealed to 212 Brinell or less. It's a mighty easy steel to machine, especially when its all-around performance is considered.

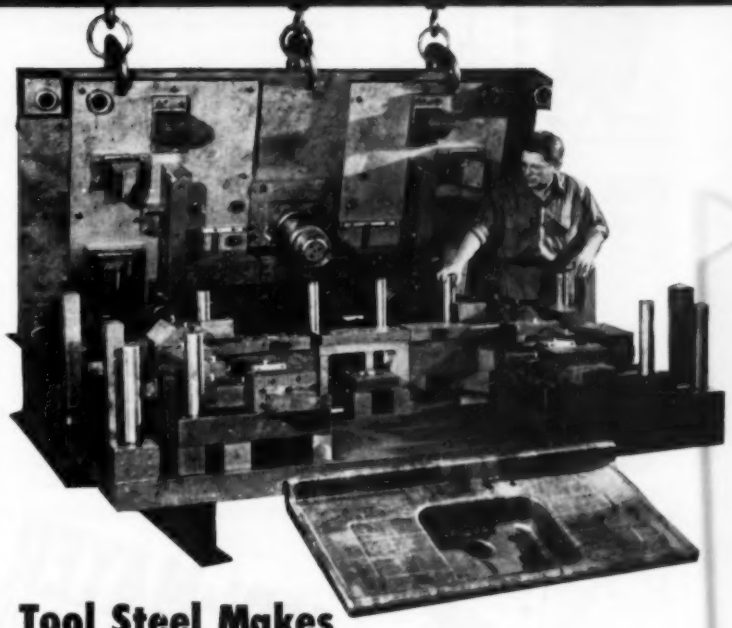
A-H5 is a general-purpose steel, suitable for nearly all tool and die jobs. Requiring a less drastic quench than standard oil-hardening grades, it also has greater wear-resistance, reduced distortion in heat-treatment, good shock properties. And its cost is on a par with the general-purpose, oil-hardening grades.

A-H5 is a steel worth looking into if you're looking for a safe, long-wearing tool-and-die grade that doesn't have to be pampered when it comes to machining and heat-treating.

Typical analysis:

C	Mn	Cr	Mo	V
1.00	0.60	5.25	1.00	0.25

Machining air-hardening tool steel causes no headaches in this shop because they're using A-H5. This user reports long wear and minimum distortion on a wide range of trimming and blanking dies.



Tool Steel Makes Kitchen Sinks, Too

Here's a man-sized die designed and built by A. F. & G. Tool & Die Co., Inc., Baltimore. Having wearing parts entirely of our BTR tool steel, this die is used to trim and pierce five different sizes of 14-gage steel kitchen sinks, one of which is shown in the foreground. Hardened to Rockwell C-56 to 58, this mammoth die will see service in a 250-ton press.

BTR, you know, is our general-purpose type of oil-hardening steel. It wears a long, long time and distorts very little in heat-treatment. Best of all, it's an economical steel that's easy to machine, easy to heat-treat.

Our Tool Steel Engineer Says:

Remove the entire surface of tool steel bars

It's important to remove the outside surface of tool-steel bars, even though portions of this surface do not serve as a working surface of the tool or die. Higher hardening stresses are set up in heat-treating a tool that has any decarburized surface.

Equal amounts of stock should be removed from *all* sides of a bar. This avoids warpage of the tool during heat-treatment. Sometimes a toolmaker will merely "skin" one surface of a flat bar and then, in order to arrive at the required thickness, remove all the remaining steel from the other surface. This is bad practice, not only because it invites warpage, but also because it is an incomplete removal of decarburization from the skinned side.

Bethlehem ULTRASONIC TESTED **Tool Steel**

MERRILL
MATERIALS HANDLING
DEVICES

MERRILL BROTHERS
56-31 ARNOLD AVENUE
MASPETH, N. Y.

Low-Temperature Embrittlement of Welds

(Continued from p. 168)

ous across the whole section, whereas in the other welds tested, the fracture originated in the weld and was arrested outside the weld. It is also of interest that only the former welds were characterized by the combination of low hydrogen content and the absence of microcracks.

Fatigue Tests — Two groups of all-weld-metal fatigue specimens were tested in a 10,000-r.p.m. fatigue testing machine of the rotating cantilever type. Only the first group contained microcracks. The fatigue specimen was 4 in. long and of ½ in. diameter, reduced at the center by a 2½-in. radius curve to ¼ in. diameter.

The presence of microcracks has a strongly adverse effect on the fatigue strength of the welds. Peculiarly, the sound weld metal specimens exhibited a higher fatigue strength than specimens cut from the parent plate, their strength at 5×10^6 cycles being 44,000 and 32,000 psi. respectively.

Notch-Impact Tests — The impact specimens were machined from transverse sections taken across E6010 bead-on-plate specimens. The geometry of the test specimen was that of a half-thickness Charpy specimen containing a half-depth Izod notch located entirely in the weld metal. This choice of geometry caused the weld to extend 40% of the way through the region under the notch. The specimens were broken in a Charpy-type testing machine at a hammer energy of 110 ft-lb. Testing temperature ranged from +75 to −100° F.

Three groups of specimens were tested, two of which contained no microcracks; these comprised E6010 welds that were air cooled, and E6016 and E6010 welds quenched in water at 70° F. The adverse effect of microcracks is clearly evident from the results of the tests.

MICROCRACKS IN WELDING PRACTICE

Two welds, more typical of general practice than the test welds, were made with ⅛-in. E6010 electrodes and were found to contain numerous microcracks. These welds were a 70° double-V six-pass butt weld in ¾ x 9 x 18-in. plate (interpass temperature 70° F.) and an intermittent fillet weld consisting of 3-in. beads on 9-in. centers joining two long pieces of ¾ x 4-in.

(Continued on p. 172)

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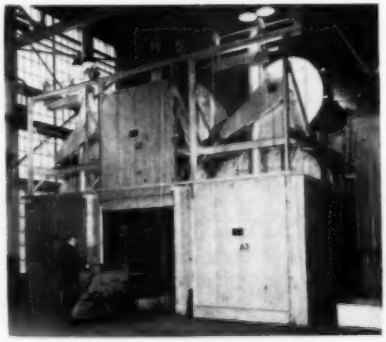

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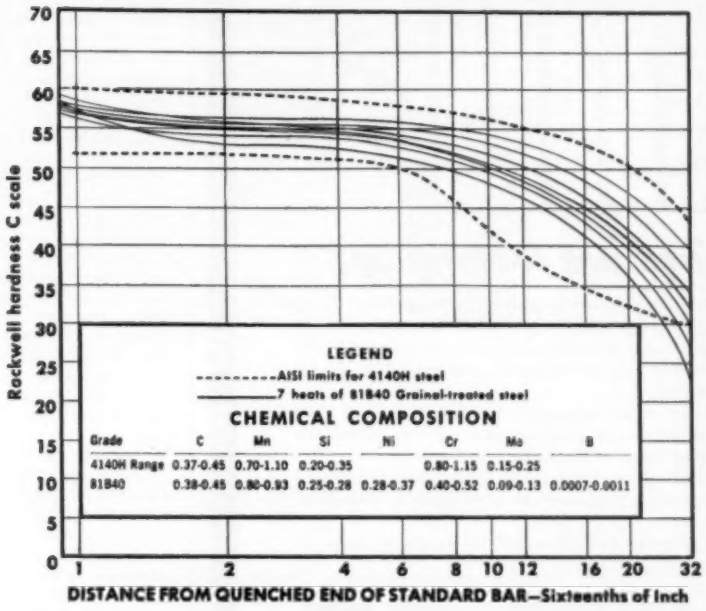

Consistent Hardenability obtained in Boron Steels made with GRAINAL ALLOYS

The most common test for boron steels is measurement of hardenability by the end quench or Jominy hardenability test. Today's steel substitutions are made on the basis of similar hardenability since a reasonable prediction can thus be made of the hardness and strength of a given part.

The curves above show the relationship between the hardenability of a series of seven heats of 81B40 steel and the hardenability band for 4140H steel, which it often replaces. The 81B40 heats were made in one electric furnace shop, and the remarkably consistent hardenability shown by the curves was obtained by the use of Grainal alloy as the means of adding the boron.

Consistent hardenability means consistent strength and hardness after heat treatment, which is the aim of every fabricator. The best proof that the Grainal alloys insure this objective is found in the successful use of three million tons of Grainal-treated steels.

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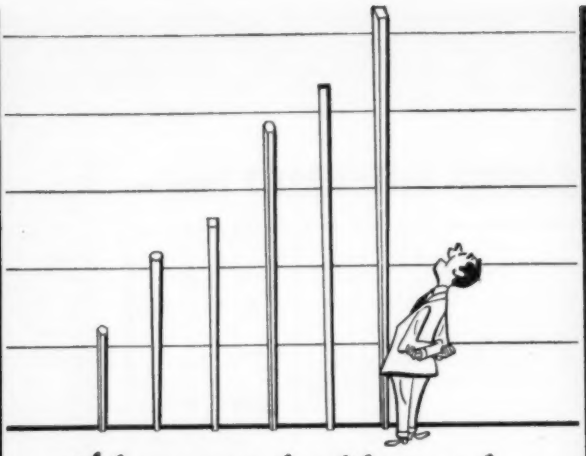

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Low-Temperature Embrittlement of Welds

(Continued from p. 170)

plate. Both welds were air cooled.

Multipass welds were made with E6016 electrodes and examined for microcracks. This test confirmed results reported by Rollason and Roberts (*Journal* of the Iron and Steel Institute, October 1950) that the first three passes are free from microcracks but the later passes exhibit a number of them. One is led to suspect a significant build-up of hydrogen in the later passes of "low hydrogen" multipass welds as these authors suggest.

Distribution of Microcracks — It has been the experience of the authors that microcracks are most conveniently detected on sections which have been electrolytically polished but not etched. Perchloric acid – acetic anhydride and chromium trioxide – acetic acid solutions have been used as electrolytes. The microcracks become more prominent with longer periods in the polishing cell.

The number of microcracks per unit area was found to vary with the orientation of the section; for example, the middle inch of a 9-in. E6010 weld exhibits about five fissures per transverse section and about 75 fissures for the longitudinal inch of section; while on a longitudinal plane parallel to the surface of the plate, about 600 fissures occurred for each inch.

The authors have observed that the fissures tend to concentrate in the interior of the weld metal and seldom, if ever, occur in regions near the external surfaces or the fusion line. Such a distribution supports the belief that hydrogen concentration is a factor of prime importance in the formation of microcracks. Further, due to this observed distribution, it is conceivable that misleading results may be obtained from notched specimens if the notch is placed in a fissure-free region.

BORDERLINE COOLING RATES

Consideration of a plot of bend angle at specified failure condition versus length of weld bead (on ¾ x 4 x 9-in. plate) shows an abrupt transition in ductility in the neighborhood of 4-in. length of weld bead. In this area, both low and high values of ductility were obtained. Microscopic examination revealed no microcracks in the 4-in. welds, and it seemed that

(Continued on p. 174)

No More "Blue Mondays" in your Plant

Every working day is a "washday" of sorts in metalworking plants like yours. Because there are plenty of production line cleaning jobs that call for the removal of dirt . . . soil, oil, dust, rust, greases, films and compounds of many kinds.

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Houghton research over the years—constantly finding new ways to speed processing in metalworking plants—has resulted in products that are helping to make metal cleaning, pickling, plating, tumbling and similar operations more efficient. And at lower costs, metalworking plants report.

Some of these popular Houghton products are described on this page. For further information—and a list of other Houghton products relating to your cleaning problems—ask the Houghton Man when he calls at your plant. Or write directly to E. F. Houghton & Co., Philadelphia 33, Pa.

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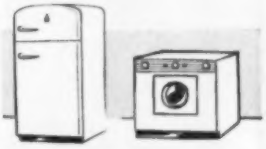
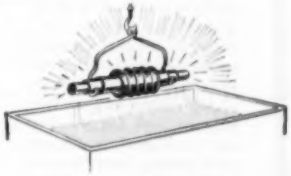
Tough Cleaning Jobs Turn "Sissy" *when Houghto-Clean 220* is used. This popular emulsion-type metal cleaner works fast . . . and it's often used in place of alkaline cleaning. Effective in spray, dip or power washing (diluted as much as 1 to 50!). Like further information?

Cleaning of Parts for Chrome Plating is swift and sure when one of Houghton's *"Cerfak"* synthetic detergents is used in the bath. A prominent car manufacturer, for example, has reported switching to "Cerfak" after extensive tests because it has such exceptional wetting ability and detergency in the pre-plating bath.



Paints "Hold Tighter" after metal is cleaned with *Houghto-Clean 313*. A phosphate cleaner that provides a perfect bonding agent. Leaves a light tough film that "anchors" paints, enamels and lacquers to metals. Also helps prevent corrosion if finish is scratched or broken. A type for either ferrous or non-ferrous metals.



Cleaning Oil-Quenched Work is a job best suited for Houghton's *Cerfak Liquid*—ideal for work heat treated in salt baths. Manufacturers find Cerfak Liquid 6 to 10 times faster than old style cleaners. Only a short soak is needed. *Cerfak Liquid* works so thoroughly that hand brushing of threaded and recessed parts is eliminated. Being so economical, it's widely used for around-the-plant cleaning, too.

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Low-Temperature Embrittlement of Welds

(Continued from p. 172)

embrittlement was occurring in the absence of microcracks.

It was known from earlier tests that, in the absence of microcracks, the fractures ordinarily tended to originate in the rough surface of the weld on unnotched specimens. Tests were made on borderline (4-in.) welds and it was found that the first fractures originated in the interior precisely in the region where microcracks would have been expected had they been discernible. Microcracks too small to be resolved by the microscope may have been present or the area may have been predisposed to the formation of microcracks upon straining. Tests upon postheated 4-in. welds are to be carried out to investigate the latter supposition.

As already noted, more work will be carried out on the borderline cooling rate condition. Also, work designed to give a clearer understanding of the function of hydrogen, nitrogen, retained austenite and certain observations bearing on the mechanism of fissuring will be reported in a later paper.

S. A. AGNEW

The Effect of Iron on the Corrosion Resistance of Copper-Nickel Alloys*

THE ADDITION of 1 to 2% iron to a nickel-bronze (5 to 10% nickel, remainder copper) produces an alloy highly resistant to sea-water corrosion, and one that can be readily hot and cold worked. Interest centers around the fact that copper holds no iron in solid solution, but that the addition of 4% nickel gives a solubility of iron of the order of 13%. This solubility falls off as the nickel content rises — at 30% nickel it is 3% and at 70% nickel the iron solubility is only 1%.

Tests were made using jets of sea water, usually containing 3% by volume of occluded air, that impinged on the metal surface at a speed of 15 ft. per sec.; the water was recirculated during each test which lasted four weeks. Because sea water is far from a standard medium, being affected by the organisms present and a variableness

(Continued on p. 176)

*Abstract of "Copper-Nickel-Iron Alloys Resistant to Sea Water Corrosion", by G. L. Bailey, *Journal*, Institute of Metals, Vol. 79, July 1951, p. 243-292.

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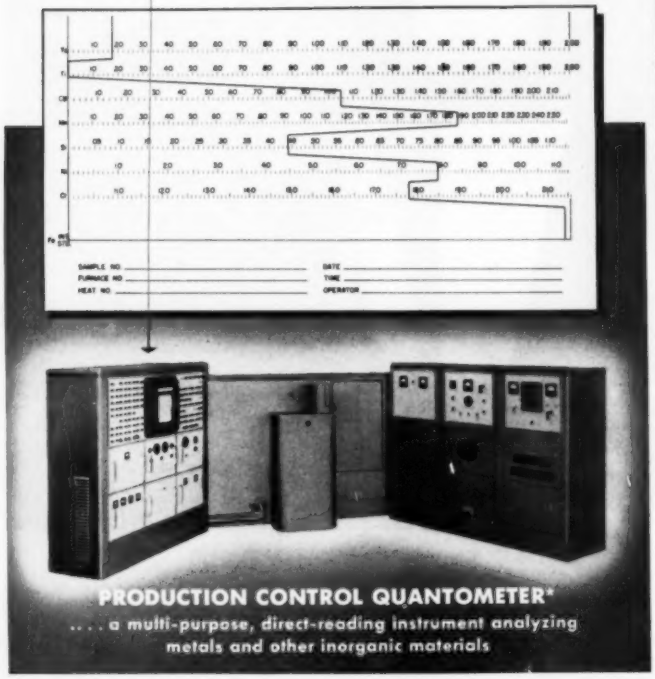

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Effect of Iron

(Continued from p. 174)

in composition, many tests were made to get a reasonably dependable average. The effect of iron (up to 32%) and manganese on resistance of 70 copper – 30 nickel alloy is reported. Other alloys of nickel and copper to which varying amounts of iron were added are discussed, as are various heat treatments. Photographic evidence is submitted to show the superiority of the iron-containing nickel-bronzes to seawater corrosion. A table shows the comparison between arsenical copper, admiralty brass, aluminum-brass, cupronickel and three copper-nickel-iron alloys.

The alloys containing 5 to 10% nickel and 1 to 2% iron can be readily cold worked whatever the heat treatment or structure, and hot worked if suitable precautions are taken. The causes of cracking are reported. H. J. Roast

Mold Blowing Reaction*

One of the persistent problems in the casting of molten metal into chill molds made of iron or steel is the appearance of holes starting from the interface and enlarging toward the inside surface. The investigation by the writers throws much light upon this reaction.

By inserting disks of various ferrous alloys into a carbon mold and pouring nonferrous alloys on these disks, it was found that tin-phosphorus, leaded bronzes and certain nickel-silvers are good examples of alloys which show "blowing" reaction; brasses and aluminum-bronzes do not react similarly. The blowing is corrected by using a mold of other than ferrous metal, or to cover the surface of the iron mold with some material that will insulate the iron from the heat of the molten metal. Another solution is the application of "active" mold dressings which bind the oxygen by the formation of solid instead of gaseous oxide products.

The more Fe_3C that is in solution in the ferrous alloy used for the mold, the greater the gassing effect. Pure graphite does not blow. A thermodynamic analysis is given, and a chart shows the standard free-energy change of oxidations of some elements in this reaction.

*Abstract of "A Contribution on the Metallic Mold Blowing Reaction", by V. Kondic, G. Martin and K. Bromage, *Metallurgia*, Vol. 45, March 1952, p. 127.

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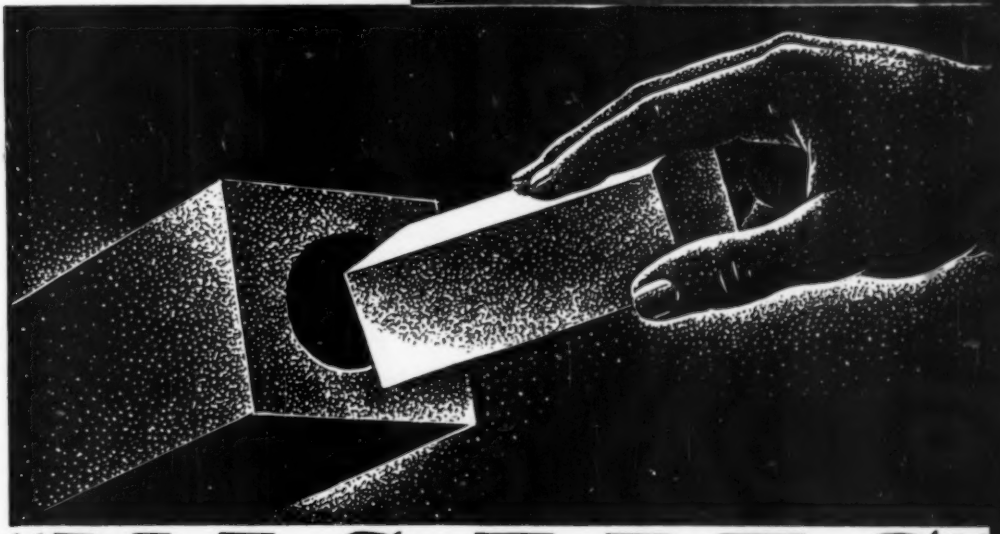

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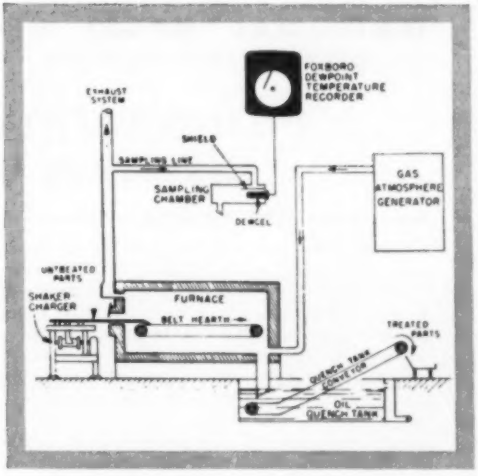

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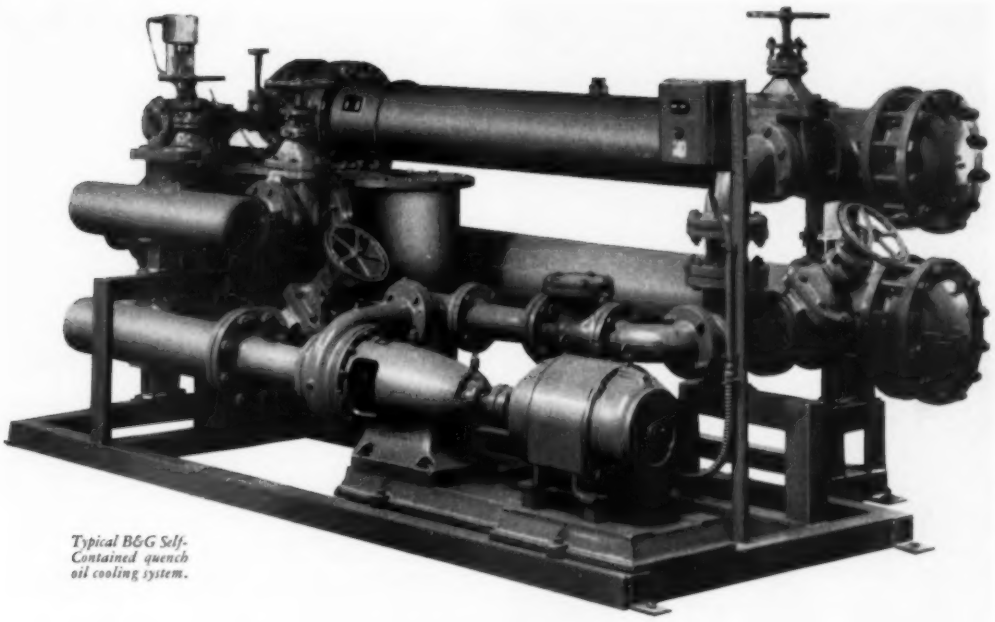

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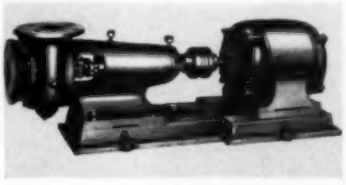

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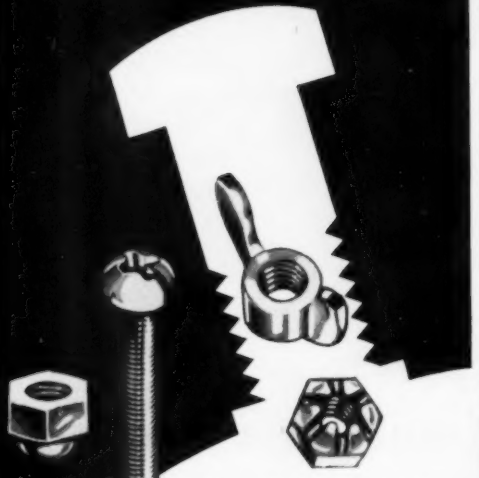

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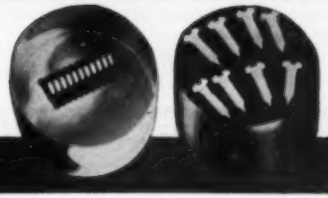

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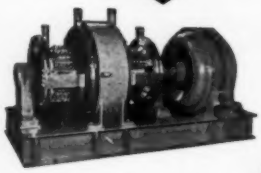

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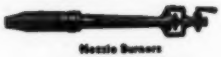

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A sheet of MicroRold .0475 thick with a tolerance of only 3% would weigh 59.85 pounds thus insuring a saving of 3.15 pounds from the theoretical average-weight, or 5.67 pounds from the maximum, while still remaining within the 18 gauge ordering range.

Weight of One Sheet of 18 Gauge 36″ x 120″ Plus or Minus 10%	Theoretical Wt. 63.00 Pounds
.052″—65.52 Pounds	
.051″—64.26 Pounds	
.050″—63.00 Pounds	
.049″—61.74 Pounds	
.048″—60.48 Pounds	
.047″—59.22 Pounds	

Weight of the same size sheet of .0475 plus or minus 3% is 59.85 pounds with an average saving of 3.15 pounds per sheet.

Multiply this saving by the number of sheets you use per month and the price per pound and you have a good dollar and cents reason for buying MicroRold.

** Each additional 1/1000″ of thickness adds 1.26 pounds weight per sheet.*

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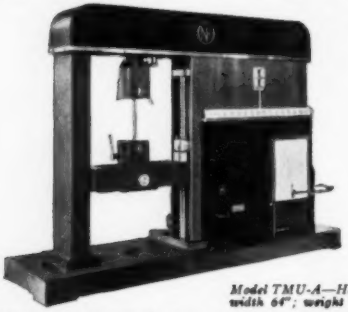

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users of FERRO-BORON in Steel Making
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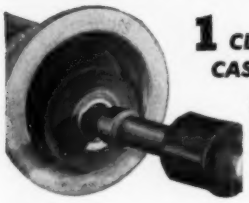

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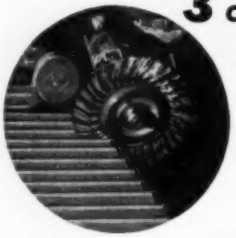

3 CLEANING WELDS in close quarters!

Allis-Chalmers' problem was to find a brush narrow enough to fit between cooling fins of transformer radiators, yet strong enough to remove slag and spall on welds which could conceal pressure-reducing pinholes. Pittsburgh engineers recommended an 8" rotary wire brush. Problem was solved!

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Throat—4" deep. Gap—10" high. Weight—27 lbs.

Eliminates excessive material handling costs in routine and special Brinell hardness testing. The King Portable Brinell can be carried to the work, used in any position, and always puts an actual load of 3000 kg. on the 10-mm. ball indenter.

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Simple to operate, the tester is impossible to overload, and even with inexperienced operators will provide consistent accurate results well within the requirements of the Bureau of Standards.

ANDREW KING

BOX 606 A

ARDMORE, PENNA.

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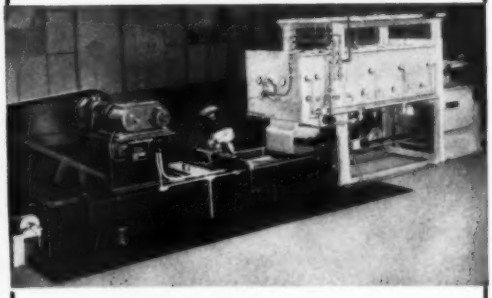
HARDENING AND QUENCHING



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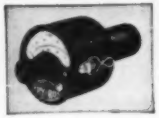
. . . when you can see it!



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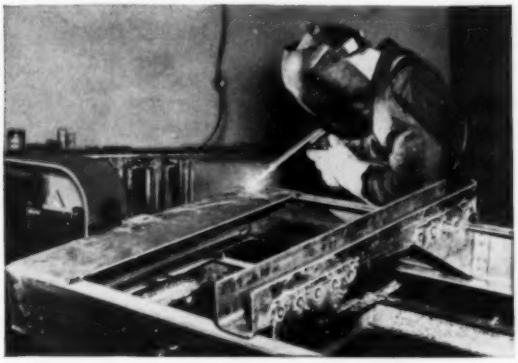
Trailers manufactured by the Marotta Engineering Co., Boonton, N. J., for use on U. S. Air Force bases. They are used singly or in trains to move supplies rapidly for plane loadings.



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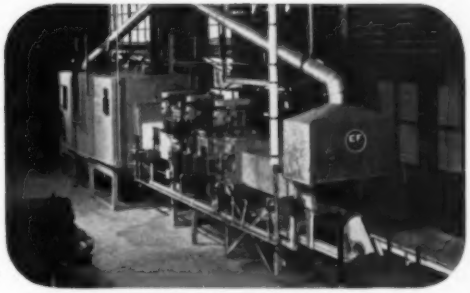

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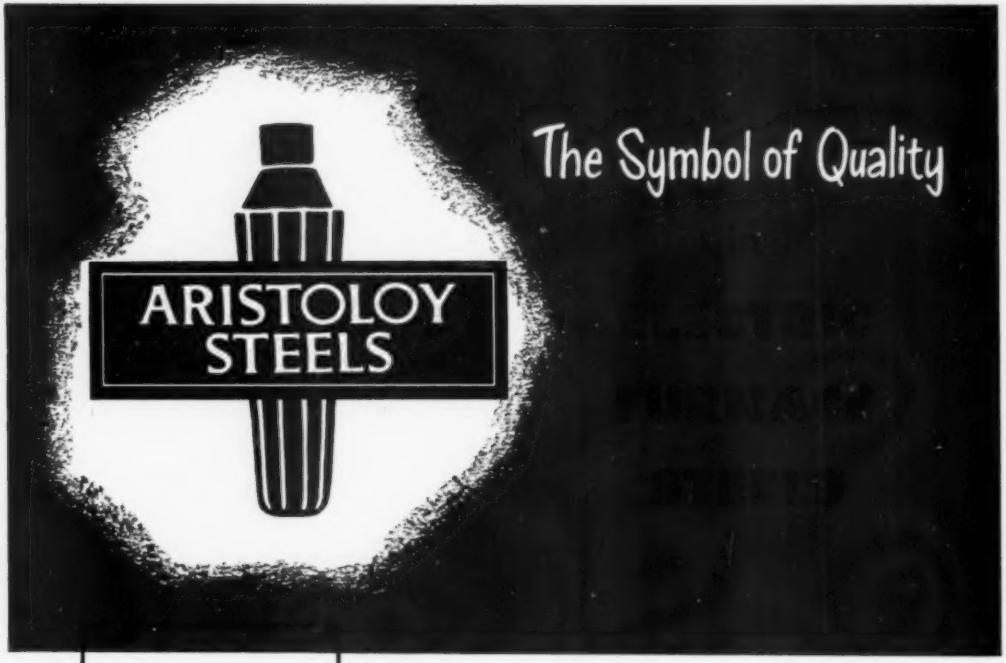

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